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Phase 1 Remedial Investigation Report

Pools Prairie Superfund Site
Newton County, Missouri

40507377

Dedicated to John Moylan.

John brought us his lifetime geologic wisdom and enthusiasm. He gave us his gifts of teaching and sharing. He gave each of us the hope that we too may someday embody his fusion of wisdom and the sparkle in the eye. Thanks, John.

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List of Acronyms

1,1-DCE	1,1-dichloroethylene
1,2-DCE	1,2-dichloroethylene
AMSL	Above Mean Sea Level
AOC	Administrative Settlement Agreement and Order on Consent
BGS	Below Ground Surface
CFS	Cubic Feet per Second
COPC	Contaminant of Potential Concern
CTA	Components Test Area
EPA	Environmental Protection Agency
ETA	Engine Test Area
GPM	Gallons per Minute
MCL	Maximum contaminant level
MDNR	Missouri Department of Natural Resources
MPA	Manufacturing Plant Area
NRCS	Natural Resources Conservation Service
OBI	Optical Borehole Imaging
OCU	Ozark Confining Unit
PCE	Tetrachloroethylene
QRA	Quince Road Area
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
SPA	Springfield Plateau Aquifer
SVE	Soil vapor extraction
TCE	Trichloroethylene
USGS	U.S. Geological Survey
VOC	Volatile organic compound

Executive Summary

This report presents the activities performed and results of the Phase 1 Remedial Investigation (RI) conducted at the Pools Prairie Superfund Site located in Newton County, Missouri. [1] This work was performed under Administrative Settlement Agreement and Order on Consent (AOC), Docket No. CERCLA-07-2011-0014, issued by the United States Environmental Protection Agency (EPA). The objectives of the Phase 1 RI were to develop a better understanding of groundwater flow in the Springfield Plateau (shallow) and Ozark (deep) aquifers, including:

1) the relationship between geological features and groundwater flow and the vertical groundwater gradients and flow between the two aquifers; and, in advance of the full RI,
2) the relationship between groundwater flow and Contaminants of Potential Concern (COPC) distribution in groundwater, springs and surface water.

These objectives were fully addressed as a result of this work, which has provided a better hydrogeologic understanding of the Phase 1 RI Study Area (Study Area) that will facilitate scoping and performance of work for the next AOC for the Remedial Investigation/Feasibility Study (RI/FS).[2]

The Phase 1 RI confirmed that the Ozark Confining Unit (OCU), which separates the Springfield Plateau Aquifer (SPA) from the Ozark Aquifer, is present and continuous across the Study Area and that the majority of groundwater flow occurs in the shallow part of the SPA, from approximately 0-130 feet below ground surface (ft bgs). Relatively little flow occurs in the SPA below the weathered bedrock, and minimal recharge passes through the OCU. Private water sampling results were generally consistent with, or lower than past sampling events, and water samples collected from source areas were consistent with past sampling events; the majority of wells showed stable or lower concentrations. Results of the source area sampling are consistent with the expected benefits of past source area removal actions. In addition, no new potential source areas were identified and the Indian Creek watershed is not affected by groundwater from any of the source areas.

Extensive work was completed in multiple stages of field activities from 2012 - 2015. This extensive work not only addressed the requirements of the AOC, but has also provided supplemental information that will be integrated into the RI/FS. Work completed under the Phase 1 RI included:

- Background study including research of available historical information.
- Private water sampling, with multiple sampling events, at up to 58 locations per event.
- Five well gauging events, with 85 to 101 wells per event, including source area wells.
- Quarterly stream and spring sampling (four events; 10 or more springs and 10 or more stream locations per event).
- Supplemental sampling of 19 additional springs and 13 stream locations.
- Detailed flow measurements at select springs and streams, including high and low flow events.
- Installation of 9 new monitoring wells.
- 10,000 feet of optical borehole imaging on 9 new and 28 existing wells.
- Downhole borehole testing including geophysical testing (12 wells), flowmeter testing (8 wells), and packer testing (5 wells).
- Permeability testing of select core samples.
- Evaluation of other potential source areas.

[1] The Pools Prairie Superfund Site (Site) as defined in the AOC, includes the Manufacturing Plant, Building 900 (Quince Road Area), the Engine Test Area, the Components Test Area, "and all areas where Waste Materials released from these areas have come to be located."
[2] The boundary of the Phase 1 RI Study Area (Study Area) as defined in the AOC, is shown in Figure 1-1.

Specific findings are outlined in more detail below:

Geologic Setting

The Study Area is located in the Springfield Plateau groundwater province, which extends across much of southwestern Missouri and adjacent areas. Within the Springfield Plateau, the shallow SPA is a low-producing cherty limestone aquifer. Bedrock is typically covered by a thick layer of cherty residuum that grades into a zone of highly weathered bedrock. While the Study Area is characterized as a karst region, there are few sinkholes and little cave development, with negligible effects on the topography. While there are classic karst features present in the Study Area, thick deposits of highly conductive chert gravel in stream channels appear to be a major contributor to the very high prevalence of losing streams in the Study Area. Springs appear to be associated with the highly conductive chert zones and alluvial storage, in addition to solutioned bedding planes and probable solutioned joints in the shallow SPA. The deep Ozark Aquifer is a regional aquifer and is separated from the shallow SPA by the OCU, which is composed of shales, sandstone and low-permeability limestones, and by the deeper SPA, which is characterized by relatively low conductivity limestones.

Ozark Confining Unit

Consistent with published information, the OCU was confirmed as being continuous in the Study Area and providing a separation between water-bearing zones of the SPA and the Ozark Aquifer. The OCU, which includes the Chattanooga Shale, Sylamore Sandstone, the Compton and Northview Formations, and probably the Pierson Formation, ranges in thickness from approximately 30 to 50 feet in the Study Area.[3] The laboratory-measured permeability of the Chattanooga Shale, the least permeable member of the OCU, ranged from 2.2E-06 to 4.0E-06 ft/day, which is consistent with United States Geological Survey (USGS) modeling. Multiple existing private water supply wells with trichloroethylene (TCE) detections are open to both aquifers, providing potential conduits between them.[4]

Refined Conceptual Site Model - Hydrogeologic Understanding

The majority of groundwater flow occurs in the shallow part of the SPA, from approximately 0-130 ft bgs, with flow toward known discharge locations. Relatively little flow occurs below the weathered bedrock of the SPA and minimal recharge (estimated at 0.1 to 0.2 inch per year) passes through the OCU. At the Engine Test Area (ETA), Components Test Area (CTA) and Manufacturing Plant Area (MPA), which are all in the Hickory Creek watershed, precipitation that enters the groundwater system (recharge) flows rapidly through highly permeable chert zones (located within the cherty residuum), the weathered bedrock present above the water table, and probably solutioned joints, in the zone termed the epikarst. At the Quince Road Area (QRA), which is in the Buffalo Creek watershed and underlain by low-permeability soil, little infiltration occurs, and most recharge that does occur flows through the weathered bedrock. In all four source areas, most of this recharge is discharged to springs and streams. Relatively little recharge moves below the weathered bedrock. While there is a downward gradient from the SPA to the Ozark Aquifer (with up to approximately 200 ft of head difference between the aquifers), based on data collected to date, minimal recharge passes through the deeper SPA and the OCU. Because the horizontal permeability of the uppermost strata is many orders of magnitude greater than the vertical permeability of the lower SPA and the OCU, the majority of the recharge to the SPA flows laterally to springs and streams, in spite of the smaller head and longer flow path. The groundwater flow direction in the Ozark Aquifer is generally from east to west in the Study Area.

Private Water Sampling

Private water sampling results were consistent with, or lower than past sampling events, except for one well near the QRA. TCE greater than 5 µg/L was identified in private water in a previously-unsampled area in the Buffalo Creek watershed, and the Public Water Supply system was expanded to this area in 2014. Private water samples in the Hickory Creek area generally indicate stable or lower TCE concentrations following removal actions at various source areas.

Existing Source Areas

Sampling of monitoring wells at the identified source areas was consistent with past sampling events; the majority of wells showed stable or lower concentrations. Results of the various sampling events are consistent with the expected benefits of past source area removal actions, with the majority of samples showing declining or stable contaminant trends. Limited locations at each source area may warrant further consideration during the RI/FS.

[3] The basis for including the Pierson in the OCU is presented in this report. The OCU thickness of 30 to 50 ft includes the Pierson.
[4] These are within an area supplied with city water (i.e., these wells are no longer needed for private water supply.)

Other Potential Source Areas

No new potential source areas were identified. Based on historical chemical usage and potential releases from other facilities, evaluation of other potential source areas was focused on an area southwest of the MPA. Sampling results from four new wells installed in this area to investigate new potential source areas did not indicate the presence of additional source areas.

Recommendations for the RI/FS

The Phase 1 RI provided sufficient information to scope and perform the next phase of work: the RI/FS. The RI/FS Study Area would be defined as two focus areas: 1) the Northeast Focus Area, which includes the ETA/CTA/MPA source areas and areas downgradient, and 2) the West Focus Area, which includes the QRA source area and areas downgradient. The Northeast Focus Area would be within the Hickory Creek watershed, largely bounded by Elm Spring Branch to the east and Hickory Creek to the north. The West Focus Area would be within the Buffalo Creek watershed. The Indian Creek watershed does not need to be included in the scope of the RI/FS because it is not affected by groundwater from the source areas. Extensive data from wells, dye traces and spring and stream samples indicates that SPA groundwater flow from the ETA, CTA and MPA remains in the Hickory Creek watershed and that SPA groundwater flow from the QRA remains in the Buffalo Creek watershed. No detections of TCE have been found in the Indian Creek watershed.

RI/FS activities would include the following items:

- Further characterization of the extent of contamination at identified source areas, including lateral extent of remaining areas of elevated VOC concentrations. This would also include establishing the vertical extent of VOC impact in the SPA in the vicinity of highest shallow TCE groundwater detections at source areas.
- Evaluation of existing data and potential collection of additional data to assess plume stability, including potential for migration of constituents outside of the focus areas.
- Additional evaluation of the Ozark Aquifer to confirm the conceptual site model.
- Further monitoring of groundwater and surface water from springs and streams within the focus areas to update site data.
- Evaluation of existing monitoring wells. The RI/FS should address the most efficient and effective means for long-term monitoring, including use of surface water monitoring and optimization of groundwater monitoring.
- Assessment of vapor intrusion in areas impacted by TCE in groundwater.
- Human health risk assessment to evaluate potential exposure to VOCs in surface water and indoor air (from vapor intrusion); and potential exposure to VOCs with the current use of wells with elevated TCE: dermal contact, inhalation and incidental ingestion.
- Consideration of a screening level ecological risk assessment to address potential impacts to ecological receptors. VOC detections in surface water are low enough that a screening level assessment may be sufficient.
- Feasibility study of remedial alternatives.

1 Introduction

This report presents the activities performed and results of the Phase 1 Remedial Investigation (RI) conducted at the Pools Prairie Superfund Site located in Newton County, Missouri.[5] This work was performed under Administrative Settlement Agreement and Order on Consent (AOC), Docket No. CERCLA-07-2011-0014, issued by the United States Environmental Protection Agency (EPA). This report was prepared on behalf of the Phase 1 RI AOC respondents: The Boeing Company, TDY Industries, LLC, Dallas Airmotive Inc. and the United States Department of Defense. This Phase 1 RI report satisfies the requirements of the AOC for the Phase 1 RI Study Area (Study Area) and also describes additional work performed to support subsequent activities.[6] In accordance with the AOC, this Phase 1 RI report also includes recommendations for the scope of the next phase of work, the Remedial Investigation/Feasibility Study (RI/FS).

1.1 Site History and Background

The Pools Prairie Superfund Site is located in Newton County, Missouri (Figure 1-1). In the 1940s, the United States government acquired approximately 43,000 acres of agricultural and residential land in Newton County to construct a U.S. Army installation named Fort Crowder. In the 1950s, a portion of Fort Crowder was transferred to the Air Force for construction of a rocket engine manufacturing plant, known as Air Force Plant No. 65 (Plant 65). This installation included the Manufacturing Plant, the Test Site, and later included Building 900. The Manufacturing Plant was used to manufacture rocket engines and related components. The Test Site, which included the Engine Test Area (ETA) and Components Test Area (CTA), was used to test rocket engines, related components, and small research engines. Building 900 had been constructed in the 1940s for use as the base laundry. In approximately 1964, Building 900 was added to Air Force Plant 65 and was converted for use as a warehouse. The 900 Building and surrounding area is now referred to as the Quince Road Area (QRA).

Operations associated with former Plant 65 began with the start of manufacturing activities at the Manufacturing Plant Area (MPA) in 1957 and were conducted to varying extent at the various areas until 1968. Rocket engine testing and related activities were stopped at the ETA and CTA in 1968; the CTA was subsequently used for jet engine overhaul and testing activities until about 1973. The ETA is still owned by the United States and is part of Camp Crowder, an active facility used by the Missouri Army National Guard. The CTA, which was sold in 1976 to the Water and Wastewater Technical School, Inc., has been unoccupied for a number of years and consists of heavily-vegetated land surrounded by Camp Crowder. Beginning in approximately 1968, the Manufacturing Plant was used to manufacture, test, and refurbish jet airplane engines. The plant was sold in 1980 and subsequently used as an active privately-owned facility for testing and refurbishing jet and helicopter engines. Building 900 was also sold and temporarily used to support jet engine overhaul and manufacturing activities. The original building has subsequently been largely demolished and replaced with new construction used for general storage.

Chemicals associated with historical operations at Plant 65 have been detected in soil and groundwater at each of the four historical areas discussed above (CTA, ETA, MPA, and QRA) and these areas represent the identified source areas for the Pools Prairie Site. Further details of the history of each of the source areas are provided in Appendix A.

1.2 Purpose of Report

The Phase 1 RI was performed at the Study Area to meet the following objectives, as stated in the AOC:

Develop a better understanding of groundwater flow in the Springfield Plateau (shallow) and Ozark (deep) aquifers, including:

1) *the relationship between geological features and groundwater flow and the vertical groundwater gradients and flow between the two aquifers; and, in advance of the full RI,*
2) *the relationship between groundwater flow and Contaminants of Potential Concern (COPC) distribution in groundwater, springs and surface water.*

[5] The Pools Prairie Superfund Site as defined in the AOC, includes the Manufacturing Plant, Building 900 (Quince Road Area), the Engine Test Area, the Components Test Area, “and all areas where Waste Materials released from these areas have come to be located.”
[6] The boundary of the Study Area as defined in the AOC, are shown in Figure 1-1. This boundary is intended to be refined for the RI/FS.

The primary COPC is trichloroethylene (TCE) in groundwater. Additional COPCs, as identified in the AOC, include 1,2-dichloroethylene (1,2-DCE), 1,1-dichloroethylene (1,1-DCE), tetrachloroethylene (PCE) and vinyl chloride. All COPCs are volatile organic compounds (VOCs).

1.3 Previous Activities

Extensive investigations have been completed at the location of former Plant 65 and subsequent operations where VOCs were potentially used. Investigations completed at each of the four known source areas have indicated VOCs in soil and shallow groundwater. VOCs, primarily TCE, have also been detected in groundwater and surface water downgradient of the source areas. Removal alternatives have been evaluated and recommended actions have been specified for all four source areas. Results of these investigations and evaluations are described in further detail in the Removal Site Evaluation and Engineering Evaluation/Cost Analysis reports prepared for each source area. Removal action activities have been implemented in all four and completed in three of the identified known source areas. These removal action activities are as follows:

- **QRA:** Removal actions at the QRA consisted of soil vapor extraction (SVE) conducted from 2005 to 2008 (Arcadis 2008). An estimated 5,970 pounds of VOCs were removed via SVE.
- **CTA:** Multiple removal actions were conducted at the CTA from 1999 to 2008. The first removal action included construction of stormwater controls to reduce infiltration through impacted soils and operation of an interim groundwater collection and treatment system (MWH, 2003). Groundwater treatment consisted of air stripping and carbon adsorption. A subsequent removal action included excavation down to bedrock of the primary impacted area, the former primary lagoon, with treatment of other less impacted areas via SVE (MWH, 2009). Approximately 31,000 cubic yards of soil and weathered bedrock were excavated and treated during the removal action; an additional 3,680 pounds of VOCs were removed via SVE (MWH 2009).
- **ETA:** Removal action activities at the ETA included excavation of approximately 2,000 cubic yards from the primary impacted area, the former hazardous waste pit. An additional approximately 11,124 pounds of VOCs were removed from other less impacted areas using dual-phase extraction. The ETA removal action was completed in 2009 (Burns &McDonnell and ECC, 2011).
- **MPA:** Removal action activities were initiated at the MPA in 2015. Approximately 7,300 cubic yards of impacted soil were excavated in the late spring and summer of 2015; treatment of this soil is ongoing. On-going SVE and bioventing are expected until 2017 (FTCH 2015).

The identified source areas will have largely been addressed as the removal actions described above are completed. In addition to these activities, the City of Neosho Public Water Supply was expanded to designated areas adjacent to the city limits in 1999 – 2000. During this expansion, 233 residences that had previously used private water supply wells for potable water use were connected to the public water supply (Montgomery Watson, 2000).

1.4 Summary of Phase 1 RI Work Performed

The Phase 1 RI was performed in accordance with a work plan submitted on June 29, 2012 (URS, 2012) and approved by EPA on August 17, 2012. The work was performed to gain a better understanding of groundwater flow in the in the Study Area, including the geologic conditions that affect flow. A particular focus was the evaluation of vertical groundwater gradients and flow between the Springfield Plateau aquifer (SPA) and the Ozark Aquifer and the relationship between groundwater flow and COPC distribution in groundwater, springs and surface water.

Phase 1 RI work was conducted in two stages. The initial stage, including a comprehensive inventory of wells in the Study Area, was conducted from 2012 – 2013. Over 663 well records were reviewed from readily available information, stream and spring samples were collected and flow measurements made at approximately 27 locations during four quarterly sampling events, high and low flow spring and stream measurements were made, water samples were collected at over 50 private locations, water level data was collected from approximately 100 wells, downhole borehole imaging and geophysical analysis was conducted in existing wells, and groundwater was sampled from multiple wells in the four identified source areas associated with historical Plant 65 activities.

Informed by the extensive data collected during the first stage, additional field investigation was conducted during the second stage of the Phase 1 RI in 2014 – 2015, in accordance with the Work Plan Addendum (URS, 2014) approved by EPA on June 19, 2014. This work included installation of nine new monitoring wells, packer and flowmeter tests to analyze flow characteristics within and between the two aquifers, geophysical investigation of crossover wells, select groundwater sampling, additional spring and stream sampling, and investigation of potential additional sources areas. A summary of the completed Phase 1 RI work can be found in Table 1-1. This extensive work has resulted in a refined understanding of groundwater flow and contaminant distribution at the Study Area, and will inform the direction of the RI/FS.

2 Hydrogeologic Context

This section presents information from several sources that provides a general understanding of the geologic and hydrogeologic context for the investigation. Data sources are summarized in Appendix B.

The Study Area is located in the Springfield Plateau groundwater province (Figure 2-1) that extends across much of southwestern Missouri and adjacent areas. Within the Springfield Plateau, the shallow SPA is a low producing cherty limestone aquifer (Miller and Vandike 1997). Bedrock is typically covered by cherty residuum that grades into a zone of highly weathered bedrock. The deep Ozark Aquifer, which extends well beyond the Springfield Plateau, is a regional aquifer and is separated from the SPA by the Ozark Confining Unit (OCU), which is composed of shales, sandstone and low-permeability limestones (Figure 2-2).

2.1 Bedrock Geology

2.1.1 Structure and Stratigraphy

Except for the lineaments[7] mapped by Whitfield (discussed below), there are no mapped structural features in the Study Area (Figure 2-3) and the bedrock is nearly flat-lying, with a gentle dip (downward slope) to the northwest. The Warsaw formation is the uppermost bedrock unit in most of the Study Area, with the Burlington-Keokuk as the uppermost unit in drainages, where the Warsaw has been eroded away (Figure 2-4). While minor fractures and folding may be present, the absence of regional faulting and folding in the bedrock profile greatly simplifies the geologic picture: the stratigraphy presented in Figure 2-2 is expected to be fairly uniform throughout the Study Area. The absence of regional faulting and folding in the area also simplifies the groundwater flow, as structural features can greatly impact groundwater flow. The gentle dip of the bedrock results in Ordovician formations of the Ozark Aquifer as the uppermost bedrock at the surface in areas east of Newton County, and Pennsylvanian formations as the upper bedrock at the surface in areas to the west and north (Figure 2-3).

Whitfield's (1999) geologic mapping of the Neosho East and West 7.5 minute quadrangles included lineaments that were mapped based on surface topography (Figure 2-4). These lineaments generally follow the northeast-southwest and northwest-southeast regional bedrock fracture patterns. Whitfield noted that while it is not possible to determine what the lineaments represent, they may be bedrock features that provide pathways for groundwater flow (Whitfield 1999).

2.1.2 Karst

Miller and Vandike (1997) define karst as "a term used to denote areas where the topography is mostly formed by the dissolving of soluble rock such as limestone and dolomite." In highly developed karst areas in Missouri, the dominant topographic features are sinkholes. However, karst can exist in a range of conditions, from limestone/dolomite bedrock with minor solutioning to major karst areas with numerous caves and sinkholes such as parts of the central Ozarks of Missouri, in the Salem Plateau (Figure 2-1).

Because the relatively impermeable Pennsylvanian strata was present in the Springfield Plateau much longer than in the Salem Plateau, karst development started at a much later date in the Springfield Plateau (Miller and Vandike 1997 p 81). Karst drainage systems are not as widespread in the Springfield Plateau as in the Salem Plateau, and the largest springs, the primary outlet points for groundwater moving through karst groundwater systems, are orders of magnitude smaller in the Springfield Plateau than those found in the Salem Plateau (Miller and Vandike 1997 pp 73, 81).

Within the Springfield Plateau there are also variations in karst features. There is intense sinkhole development in Greene and northern Christian Counties in the vicinity of the City of Springfield, Missouri (estimated more than 10 sinkholes per 100 square miles); however, in most of the rest of the Springfield Plateau in Missouri, including the Study Area, sinkholes are isolated phenomena (less than 1 per 100 square miles) (Harvey 1980). See Figure 2-5 for the most recent Missouri Department of

[7] USGS defines lineaments as mappable linear surface features that are generally manifested by topography (including straight stream segments), vegetation or soil tonal alignments. Lineaments are largely a reflection of rock fractures. Accessed on October 23, 2015 at http://pubs.usgs.gov/of/2000/of00-006/htm/lineamen.htm.

Natural Resources (MDNR) mapping of sinkhole and cave density for southwest Missouri. Karst features are more abundant where chert content is relatively low (Adamski et al 1995 p 55), such as in the Springfield area compared to the Study Area.[8]

Most of the karst features in the Springfield Plateau are in the Burlington-Keokuk formation (Miller and Vandike 1997 p 87). In the Study Area, while the Warsaw is the primary bedrock surface, springs are primarily located within the Burlington-Keokuk or in the Warsaw, very close to its contact with the Burlington-Keokuk, as shown in Figure 2-4. Losing streams, on the other hand, appear to be associated with both the Warsaw and Burlington-Keokuk formations (Figure 2-6). Losing streams are very common in the Study Area, with the majority of the stream segments in the Study Area designated as losing streams (Figure 2-6; see figure for data sources).

2.2 Surficial Geology

Within the Study Area, various soil deposits cover most of the ground surface; bedrock outcrops are fairly uncommon. The hilltop prairie areas are underlain by very cherty residuum with fragipan[9] (Figure 2-7; Whitfield 1999). The fragipan tends to be more broken up in the colluvium that covers the slopes (Whitfield 1999). Alluvium, comprised mostly of chert gravel and cobbles, is mapped only if the estimated thickness is at least 10 ft (Whitfield 1999).

The Natural Resource Conservation Service (NRCS) maps soil based on runoff potential (Figure 2-8); a higher runoff potential indicates soil with low permeability or other barriers to infiltration. The areas of highest runoff potential (Hydrologic Soil Group D) generally correspond to the areas mapped as fragipan by Whitfield (1999). The areas of alluvium in Hickory and Buffalo Creeks, on the other hand, transmit water freely (Hydrologic Soil Group B). Colluvial slopes have in-between water carrying capacity. Note that the soils with the highest water conveyance capacity (Hydrologic Soil Group A) do not correspond to a specific surface geology type as mapped by Whitfield (Figure 2-9; Whitfield 1999).

2.3 Surface Water

As shown by the topography in Figure 2-6, the Study Area includes parts of three surface water drainage systems: Hickory Creek to the north and east, Buffalo Creek to the west and Indian Creek to the south.

2.4 Groundwater

In the Springfield Plateau, which includes the Study Area, the SPA is an unconfined aquifer (the water surface is open to the atmosphere), and, as is typical for an unconfined aquifer, the potentiometric surface generally reflects the overlying topography, with the groundwater flow mostly lateral toward springs and streams (Adamski et al 1995 p 55; Pope, Mehl and Coiner 2009). As an unconfined aquifer, the SPA in the Study Area is recharged by precipitation (Pope, Mehl and Coiner 2009 p 10). Miller and Vandike (1997, Table 10) report well yields of 10 to 30 gallons per minute (gpm) in the SPA; however, they do not include any specific well data. They state that the relatively chert-free limestone sequences in the Burlington-Keokuk have well-developed solution-enlarged karst features that can transmit large volumes of water (Miller and Vandike 1997 p 103). Others report that yields are commonly less than 20 gpm, and the aquifer is rarely used for public water supply (Adamski et al 1995 p 2). While they include it with the SPA, Miller and Vandike do not consider the Warsaw to be a significant as an aquifer (1997 Table 10). Czarnecki et al indicate that hydraulic conductivity estimates for the SPA are "sparse" (2010 p 10). In their model of the Ozark Aquifer, they used values of horizontal hydraulic conductivity for the SPA of 15 and 4.6 ft/day for the sub-areas that include the Study Area. Vertical hydraulic conductivity values used in their model for the sub-areas that include the Study Area were 0.3 and 0.1 ft/day (Czarnecki et al 2010 Table 6 and Figure 13).[10]

The Ozark Aquifer extends over most of southern Missouri and parts of neighboring states (Imes and Emmett 1994). It is open to the atmosphere, and hence unconfined, in the eastern part of its extent. However, in the west including Newton County, it is overlain by the OCU (Imes and Emmett 1994). Where the Ozark Aquifer is overlain by the OCU, it is a confined aquifer (water

[8] The difference in chert content between the Mississippian limestones in the karst areas of Springfield and the Study Area is observable in the Missouri Department of Natural Resource (MDNR) geologic well logs for these two areas, available at http://dnr.mo.gov/env/wrc/logmain/.
[9] Fragipan is a dense, brittle material that appears cemented and restricts the flow of water and penetration of roots.
[10] The Czarnecki et al 2010 model ("USGS model") was developed using MODFLOW 2000 and covered a 7,340 square mile area of parts of Arkansas, Kansas, Missouri and Oklahoma. The Study Area, which covers a little less than 50 square miles, lies entirely within the modeled area. The model was developed to assess the effect of increased water use on the Ozark Aquifer. Each modeled layer was divided into sub-areas with different aquifer properties.

rises above the top of the aquifer in a penetrating well). Generally speaking, the Ozark Aquifer is unconfined in the Salem Plateau and confined in the Springfield Plateau (Figure 2-1). Figure 2-10 shows the areal extent of the OCU.

Well yields within the Ozark Aquifer vary substantially. The uppermost units of the Ozark Aquifer (Jefferson City and Cotter) are not considered “important aquifers”; Miller and Vandike (1997 Table 10) report yields of 10 to 20 gpm in these formations. However, a few thin sand units, some of which may be the Swan Creek unit, have been reported in the Cotter formation in MDNR well logs in and near the Study Area. In one of these, Well 18978, the reported yield from the well log was 30 gpm.[11] The units shown in Figure 2-2 that lie below the Jefferson City formation each have the potential for yields greater than 100 gpm, with the Potosi formation having by far the highest potential yields (400 to 1,200 gpm with an average of 600 gpm [Miller and Vandike 1997 Table 10])[12] (Imes and Emmett 1994 p D47). Of 12 Ozark Aquifer wells in and near the Study Area included in a study of well yields, 6 had reported yields between 200 and 500 gpm and ranged in depth from approximately 1,000 to 1,400 feet below ground surface (ft bgs). Remaining wells were shallower and had smaller yields. Wells in the Jefferson City and Cotter Formations have reported yields of 20 to 30 gpm (Robertson et al 1963).

The Study Area was included in a model developed by the United States Geological Survey (USGS) to assess impacts of long-term pumping on the Ozark Aquifer (“USGS model”; Czarnecki et al 2010). Input and results from this model are summarized as appropriate in this section, and are part of the published information used in this investigation. In the USGS model, Czarnecki et al used Ozark Aquifer hydraulic conductivity values of 0.61 ft/day (horizontal) and 0.1 ft/day (vertical) in the sub-area that includes the Study Area (2010 Table 6 and Figure 13). OCU values used for the sub-areas that included the Study Area were 4E-05 ft/day (horizontal) and 4.0E-06 and 4.0E-07 ft/day (vertical).

2.4.1 Relationship between Geological Features and Groundwater Flow

Groundwater in a water table aquifer such as the SPA flows in response to gravity, just as surface water does. Other factors that influence groundwater flow include the hydraulic conductivity (permeability) of the media and the cross-sectional area of the flow path.

The many dye trace studies conducted in the Study Area from 1991 to 2011 (Figures 2-11A and 2-11B) reveal important information about the relationship between geological features and shallow groundwater flow.[13] Key points from these dye trace studies are as follows:

- For all but two injection points, the dye tracing results suggest that the shallow groundwater flows downslope (downgradient) and discharges at nearby springs and streams within the local drainage basin.[14] Dye traces from the ETA and CTA and drainageways near the MPA, all of which are in the Hickory Creek surface drainage area, show that shallow groundwater flow is bounded by Hickory Creek.[15]
- At two injection points in the upper reaches of Buffalo Creek, (11-02 and CC-7, Figure 2-11A), the dye did not emerge in the Buffalo Creek drainage. Rather, the dye emerged at springs such as Big Spring and Hearrell Spring, which are along Hickory Creek and well within the surface drainage area of Hickory Creek (Figure 2-11A).
- Reported mean travel times for dye injections from the ETA, CTA and area near the MPA were approximately 1,000 to 3,600 ft per day (Aley 2000 p 57, Vandike and Brookshire 1996 p 15) to detection points. There are no dye trace injection points near the QRA.
- Field observations made by the researchers conducting the dye tracing at the ETA and CTA identify coarse gravel material at the dye injection points. The researchers noted that the injection point at the ETA (CC-4, Figure 2-11A) was a pit that “would impound water only briefly as the water drained quickly through the gravelly alluvium and colluvium” (Vandike and Brookshire 1996 p 12). The injection point in the same drainageway downstream of the ETA (CC-2, Figure 2-11A) was described as a streambed consisting of “coarse alluvial gravel.” At that location, dye was

[11] The location of Well 18978 is shown in Figure 4-1. Note that yields reported on well logs are only very general indicators of actual yield, and probably usually represent an upper end value. Sustained pumping tests often show that initial apparent yields cannot be sustained.
[12] Based on correspondence from the USGS (email, February 12, 2016), the Miller and Vandike (1997) yield estimates for the Potosi may be overstated for the Study Area, where the formation is thinner than in other parts of the State. Much of the production in from the deep wells in the Study Area is from the Roubidoux Formation and Gasconade Dolomite, and maybe the Eminence Dolomite.
[13] See Figures 2-11A and 2-11B for data sources for the dye tracing.
[14] This statement is not intended to suggest that the exact flow path between the injection and discharge points of the dye is known; only that the results indicate that the flow is contained within the local drainage area, as would be expected with a water table aquifer.
[15] The figures show stations where dye was detected and do not show the many additional stations where dye was not detected. Of particular note is that dye from the ETA and CTA was not detected in McMahan Spring, a large spring on the right bank of Hickory Creek, just downstream of Unicorn Spring (Aley 2000 p 49).

placed in a hole 7 ft deep and 12 ft in diameter that had developed in the alluvium (Vandike and Brookshire 1996 p 10). At the CTA, where dye was injected into a pond (CC-5, Figure 2-11A), Vandike and Brookshire (1996 p 13) estimated that at the time of the dye trace, over 30,000 gallons of runoff water entered the pond following a heavy rain and all the water had drained away by the next day.

2.4.2 Vertical Gradients and Flow Between the SPA and the Ozark Aquifers

In a USGS study of potentiometric surfaces in the SPA and Ozark Aquifer, the depth to water of 15 non-pumping wells completed in the SPA in Newton County ranged from 50 to 152 ft bgs, with an average depth of 93 ft (Gillip, Czarnecki and Mugel 2008). Water level elevations ranged from 888 to 1265 ft above mean sea level (amsl).

The depth to water of 14 non-pumping wells completed in the Ozark Aquifer in Newton County ranged from 65 to 344 ft bgs, with an average depth of 231 ft (Gillip, Czarnecki and Mugel 2008). Water level elevations ranged from 647 to 1095 ft amsl. The general flow direction in the Ozark Aquifer in the region of the Study Area is east to west.

The regional potentiometric surfaces developed from the USGS study suggest a head difference of approximately 200 ft between the two aquifers in the Study Area (Gillip, Czarnecki and Mugel 2008).

Czarnecki et al (2010) used their model (USGS model) to estimate base year (2006) flow through the OCU as well as longer term flow with increased pumping in the Ozark Aquifer (Czarnecki et al 2010 Table 12 and Figure 35).[16] Based on the USGS model, in the modeled Study Area vicinity, slightly less than half of the annual base-year flow into the Ozark Aquifer passed through the OCU. The base-year model-derived inflow from the OCU to the Ozark Aquifer in the vicinity of the Study Area averages 0.2 inches per year. With different modeled scenarios and increased pumping, the head difference between the SPA and Ozark Aquifer increases, resulting in future modeled inflow from the OCU to Ozark Aquifer of up to 0.3 inches per year.

[16] Model assumptions are included in the USGS report (Czarnecki et al 2010).

3 Work Performed

3.1 Overview

The scope and rationale for the work performed is detailed in work plans prepared for the two major stages of fieldwork (URS 2012 and 2014). The two stages of fieldwork are summarized in Table 1-1: the first stage was conducted in 2012 and 2013 and the second stage in 2014 to 2015. Spring, stream, and well sampling and gauging were conducted in both stages. Primary additional activities in the first stage included a detailed review of existing data, geophysical surveys and optical borehole imaging (OBI) in a large number of wells, and high and low flow measurements at springs and streams. Based on these results, additional data needs were identified and addressed in the second stage. The second stage of field activities primarily included installation of monitoring wells and downhole testing in both new and existing wells.

Phase 1 RI work is summarized graphically in Figures 3-1 and 3-2, and consisted of the following:[17]

- Downhole borehole testing including flowmeter testing (9 wells), geophysical testing (12 wells), and packer testing (5 wells).
    - Downhole work is summarized in Figure 3-2.
    - Packer test results are summarized in Table 3-5.
    - Geophysical test results are included in Appendix K.
    - Flowmeter and packer testing are described and detailed in the Colog report, Appendix L.
- 10,000 ft of OBI in nine new and 28 pre-existing wells.[18]
    - Wells with OBIs are shown in Figure 3-2 and OBIs are included in Appendix G (new wells) and Appendix K (pre-existing wells).
    - OBIs have also been added to the boring logs in Appendix D.
- Installation of nine new monitoring wells.
    - The objectives and rationale for each of the new wells are included in Table 3-1.
    - Wells are summarized in Table 3-2.
    - Well locations are shown in Figures 3-2 and 3-7.
    - Boring logs, well installation reports, and registration and certification records are included in Appendix D.
    - Survey results are included in Appendix I.
- Private water sampling in multiple sampling events, at up to 58 locations per event.
    - Analytical results are tabulated in Appendix E and TCE results are shown in Figures 3-4 through 3-6.
- Sampling of 60 wells in the four source areas.
    - Analytical results are tabulated in Appendix E and TCE results are shown in Figures 3-8 through 3-11.
- Sampling of new monitoring wells.
    - Analytical results are tabulated in Appendix E and TCE results as shown in Figure 3-7.
- Quarterly stream and spring sampling (10 or more springs and 10 or more stream locations per event).

[17] Work was done in accordance with the *Phase 1 Remedial Investigation Work Plan, Pools Prairie Site, Neosho, Missouri, Docket No. CERCLA-07-2011-0014*, URS (AECOM), 2012, which included the Quality Assurance Project Plan, and the *Phase 1 Remedial Investigation Work Plan Addendum for Monitoring Well Installation*, URS (AECOM), 2014; with minor procedural changes as noted in this report. Field documentation is included in Appendix F.

[18] OBIs were not conducted in the replacement well, MW-W01; however, OBIs were conducted in both MW-W02 (which was abandoned) and its replacement, MW-W02R.

- Supplemental sampling of 19 springs and 11 stream locations.
  - Stream and spring analytical results are tabulated in Appendix E and TCE results are shown in Figure 3-12.
- Flow measurements at select springs and streams, including high and low flow events.
  - Flow measurements are presented in the Figure 3-3 series and summarized in Table 3-6, and data and additional charts are included in Appendix M.
- Five well gauging events, 86 to 101 wells per event, including source area wells.
  - Data are presented in Appendix F.
  - This data, along with results from packer tests, was used to create the SPA potentiometric surface (Figure 4-4).
- Permeability testing of select core samples.
  - Results are included in Appendix J.

3.2 New Wells

The Phase 1 RI included the installation of nine new monitoring wells.

Well MW-NE01, located downgradient of the CTA and upgradient of the highest private water and spring TCE detections, was intended to help determine the vertical extent of TCE impact in the SPA. In addition, the boring for MW-NE01 was initially drilled to the Chattanooga Formation in the OCU and core samples of the Chattanooga Formation were collected for permeability testing. The lower part of the boring was grouted to seal off the OCU before completing the well. Well MW-NE02 was installed to investigate potential impacts to the SPA west-northwest of the MPA. Wells MW-C01, -C02, -C03, and -C04 were installed to investigate potential new source areas. Well MW-C01 also provided information in the vicinity of the MPA. Well MW-W01 is a replacement well for a monitoring well that could not be found at the QRA.[19] Wells MW-W02 and -W03 were installed to assess lateral and vertical impacts at the QRA. Further rationale for the new wells is included in Table 3-1.

With the exception of MW-W01, the new wells were installed in the SPA as open-hole wells with permanent casing in the upper portion of the well. These wells were installed in stages: first the upper portion of the well was drilled and the specified testing was carried out. Then the permanent casing was installed in this upper part of the borehole, and the remainder of the well was drilled and left as an open-hole monitoring well. Specified testing was then completed in the lower part of the boring.

Wells were installed using sonic drilling techniques, with some coring in Well MW-NE01.[20] Sonic drilling was used for the majority of Well NE01 and was solely used for rock drilling in the remaining seven wells. A summary of new well installation information can be found in Table 3-2.

3.3 Geologic and Hydrogeologic Results

Summary information for existing wells in the Study Area is included in Appendix C.

3.3.1 OBIs and Geophysical Testing – Private Wells

OBIs were conducted in 28 private wells, with geophysical testing also done in several of those. OBIs were conducted for the purpose of observing geologic features that may affect groundwater flow (e.g., fractures and fracture orientation) and to determine stratigraphy. As described below, the various geophysical tests were used to provide additional data relevant to groundwater flow such as the location of shale (which impedes flow), locations of borehole irregularities (which can indicate open fractures that may be conduits for groundwater flow), and abrupt changes in electrical resistance (which can indicate groundwater inflow).

[19] Well MW-W01, the replacement well, is shown on Figure 3-9 only.
[20] The work plan (URS 2014) indicates that rock core would be collected from 8 of the 9 wells. On September 6, 2014, EPA approved the use of sonic drilling in lieu of coring if coring was problematic. Some coring was conducted in Well NE01; coring of the cherty limestone was problematic, and sonic drilling was used.

The OBIs confirmed the continuity of the stratigraphy across the Study Area (Figure 2-2), and the resulting interpretations were incorporated into the geologic cross sections for the Study Area (Figure 4-1 series). Results of geophysical testing are summarized below and included in Appendix K.

Gamma logs, which record the amount of natural gamma radiation emitted by the rocks surrounding the borehole, were taken in 12 wells.[21] The gamma logs are useful in identifying shale layers as clay and shale emit higher levels of gamma radiation. The Chattanooga Shale, in particular, has a recognizable gamma signature that is identifiable even through casing. The gamma log was used to identify the location of the Chattanooga Shale in Well 194-3, where it was cased off and therefore not visible in the OBI.

Caliper logs, which record irregularities in the borehole wall, were taken in six wells.[22] Irregularities could indicate open fractures, which are potential conduits for contaminant transport. In general, the caliper logs confirmed the lack of irregularities in the boreholes. In at least one case, vugs in the Cotter Formation (Ozark Aquifer) were noted by the calipers. Based on the OBI logs, most of the irregularities observed in the SPA appeared to be related to drill bit behavior rather than features of the bedrock.

Resistivity logs, which report the electrical resistivity of water and surrounding rock in the borehole, were taken in six wells.[23] Resistivity is primarily a function of total dissolved solids in the water. Resistivity of groundwater can range from zero to thousands of ohm-meters. Abrupt changes in resistivity could indicate inflow of water from another source. For example, water in a karst conduit that originated from recent surface water runoff may have a different resistivity signature than long-term formation water. The resistivity recorded in the six wells indicated little variation, ranging from approximately 10 to 50 ohm-meters, with most values in the 20 to 30 ohm-meter range. On all logs except A088918, the resistivity below the water level changed little, with the most notable changes on the resistivity logs being the transition from air to water in the borehole, and the reduced resistivity at the Northview and Chattanooga formations.[24]

Fracture analysis. Fractures represent flow pathways for groundwater. The dip (slope) angle and direction can provide indications of preferred flow in the horizontal and vertical directions. The size and continuity of the fracture (defined by rank) is an indicator of groundwater carrying capacity. Fracture analysis included quantifying and summarizing the following characteristics of fractures: dip angle, dip direction, and fracture ranking, based on interpreted flow characteristics.

The fracture analysis was conducted by visual observation of the OBIs by specialists at Colog. Details of fracture analyses are included in the Colog report, Appendix L. The results are summarized graphically for each well in Appendix N. Fracture ranking is summarized in Table 3-3.

Fracture analysis was conducted on one private well, Well 623. The great majority of the fractures were low-angle and with overall weak directionality, suggesting they are likely bedding plane related. The very gentle bedrock dip in the Study Area results in low angle bedding plane fractures. The weak directionality is likely from local bedding plane undulations, unrelated to regional dip.

No fractures higher than Rank 2 on the 0 to 5 ranking scale (Table 3-3) were identified in Well 623. Of the eleven Rank 2 fractures identified, seven are in the 38-ft interval from the bottom of the casing to 137 ft bgs. The fracture at 460 ft is in the Cotter Formation (Ozark); all others are in the SPA. All are low angle and appear to be related to bedding planes.

While fracture analysis was not conducted on the other private well OBIs, a visual comparison of the SPA portion of the OBIs resulted in the conclusion that Well 623 has a typical SPA profile for the Study Area, i.e., a few open fractures roughly in the upper 130 ft, with the great majority appearing to be bedding plane related. No large fractures were observed in the other private well OBIs.

[21] Wells 5570, 119, A088918, A071672, 89, 1360-2, 194-3, 905, A035143, A088629, Neosho 3, and 805-3.
[22] Wells 5570, A071672, 89, 1360-2, 905 and 805-3.
[23] Wells 5570, 119, A088918, A071672, 89 and 1360-2.
[24] In A088918, the resistivity was much more variable over the interval from approximately 346 to 417 ft, where the resistivity changed frequently with depth and ranged from approximately 7 to 30 ohm-meters. This unusual resistivity compared to the other wells did not appear to relate to fractures or significantly changed geology.

3.3.2 OBIs and Geophysical Testing – New Wells

OBIs were conducted in all new wells, except for replacement well MW-W01. The purpose of the OBIs is noted in Section 3.3.1 above. In a few cases, in the upper portion of the borehole (prior to installation of permanent casing), visibility was not sufficient to produce a clear picture and acoustical imaging was conducted. OBIs and acoustical images for new wells are included in Appendix G.

The various OBIs provided similar results, confirming the continuity of the stratigraphy throughout the Study Area (Figure 2-2), and the resulting interpretations were incorporated into the geologic cross sections for the Study Area (Figure 4-1 series).

Fracture analysis, as described in Section 3.3.1, was conducted on all new wells for which OBIs had been completed. All new wells were completed in the SPA. Similar to Well 623, the great majority of the fractures were low angle. However, unlike Well 623, most of the wells showed a dominant dip angle to the north, indicating the north-dipping (sloping) bedrock. Note that the dip is low-angle.

A summary of the results of the fracture ranking for new wells is presented in Appendix L. Detailed fracture rankings are included alongside the downhole camera images in each OBI log. No rank 4 or 5 fractures were identified. Forty Rank 2 (continuous open crack) and six Rank 3 (wide open crack) fractures were identified in the new wells below the depth of competent bedrock and the bottom of the permanent casing. Locations of the Rank 2 and 3 fractures are summarized in Table 3-3 and shown graphically in Appendix N. All of the Rank 3 fractures were found in the upper 30 ft of bedrock.[25] Of the 40 Rank 2 fractures, all but nine were in the upper 50 ft of bedrock. The geophysical tests on the new wells support the conclusions of the geophysical test on the private wells: fractures are small and mostly in the upper SPA, and almost all the fractures appear to be bedding plane related, suggesting groundwater flow is primarily lateral.

3.3.3 Flowmeter Testing – Private Wells

Flowmeter testing was used to estimate groundwater inflow and outflow in wells, and to identify the specific locations where the flow is occurring.

Flowmeter testing, described in detail in the Colog report in Appendix L, involves suspending a flowmeter into the borehole at potential water-bearing fracture locations identified from the OBIs. The flowmeter is capable of measuring flows from 0.02 to 10 gpm. It measures only vertical flow: changes in flow indicate inflow from or outflow into the borehole. For example, if the measured flow at 50 ft is 1 gpm downward and the measured flow at 52 ft is 2 gpm downward, this is interpreted as one gpm of flow entering the borehole from the formation between 50 and 52 ft.

Flowmeter testing was conducted on the following private wells, attempting both ambient and pumping (extraction) conditions at each well if pumping conditions could likely be sustained (Figure 3-2, Table 3-4):

- Well 623
- Well A035143
- Well A071672
- Well A088918

These wells are “crossover wells”: they are open to both the SPA and the Ozark aquifers. Because the wells are open to both aquifers, the static water level in each well is somewhere in between the SPA potentiometric surface and the Ozark Aquifer potentiometric surface. All four wells were cased through the weathered bedrock, with casing depths ranging from 82 to 119 ft bgs. Results of the flowmeter tests are included in Appendix L and summarized in Table 3-4.

In **Well 623**, only an ambient flow test was conducted, as the ambient flow indicated the well was unlikely to sustain sufficient flow for an extraction test. Approximately 0.5 gpm appears to be entering over the interval between the bottom of the casing (99 ft bgs) and a horizontal fracture at 299 ft. Similar downflow was measured at the bottom of the SPA. Thus, due to the head difference between the SPA and the Ozark, approximately 0.5 gpm flows under ambient conditions from the SPA to the Ozark.

[25] Well NE02 had 135 ft of overburden; an unusual depth. Field personnel reported that the well location was adjacent to a flood control structure and that excess fill from that construction appeared to have been deposited in the area of Well NE02. However, no distinction between fill and natural soil was made on the boring log. The well is in the general vicinity of the lineaments mapped by Whitfield (Figure 2-4); the unusual depth of soil could potentially be related to the lineament.

In the ambient test at Well **A035143**, a downward flow increase of approximately 0.21 gpm between 351 and 358 ft was attributed to inflow from a fracture at 351 ft bgs, near the Reeds Spring/Pierson contact (SPA). Very small additional increases in downflow were measured at other intervals, resulting in a total outflow (downflow) from the SPA into the Ozark of 0.26 gpm. In the pumping test, the water level dropped rapidly; flow measurements could be made only below 305 ft, and measured flow ranged from 0 to 0.04 gpm (downward), near the lower end of the flowmeter range. It appears that the SPA head was inducing the higher flow measured in the ambient test, and that when the head was reduced, the flow was also reduced.

In the ambient test at Well **A071672,** inflow measurements were all very low; the maximum single point interpreted inflow was 0.03 gpm at 220 ft bgs. Outflow into the Ozark at the bottom of the testing interval was 0.12 gpm. In the extraction test, the water level dropped rapidly and flow between the SPA and the Ozark reversed to 0.17 gpm upflow (the pump was within the head of the Ozark).

As a result of calibration issues at Well **A088918**, results can be considered only qualitatively. Inflow was minimal in both ambient and extraction testing, and water levels fell rapidly during pumping.

In summary, the flowmeter tests on private wells showed little vertical flow in the SPA, and pumping could not be sustained even at low rates. The maximum single interpreted inflow was 0.5 gpm in ambient testing at Well 623, over the depth interval from 99 to 299 ft. In the extraction tests water levels dropped quickly at pumping rates of around 3 gpm. Wells reportedly had 6-inch casing, which suggests an approximately 5-inch well (capacity of 1 gallon per ft of depth). The reported rates at which water levels fell under pumping conditions suggests that much of the water pumped was borehole storage, as noted in the Colog report.

3.3.4 Flowmeter Testing – New Wells

Flowmeter testing was also conducted on the following new wells, under both ambient and pumping conditions (Figure 3-2):

- MW-C01
- MW-NE01
- MW-NE02
- MW-W02/MW-W02R

Results of the flowmeter tests are included in Appendix L and summarized in Table 3-4. Testing of the upper part of each well, prior to installing the permanent casing, was conducted in October 2014 and testing of the part of the well below the permanent casing was conducted in December 2014.

As summarized in Table 3-4, small flows were measured, and measured flow rates generally decreased with depth. In all cases, the water level fell rapidly at pumping rates of 1.1 to 3.6 gpm. Except for NE02, the following were the only instances of interpreted flow rates higher than 0.1 gpm below a depth of 130 ft:

- 0.5 gpm outflow (lost to the formation) at MW-NE01 under ambient testing at 129 to 135 ft bgs,
- 0.7 gpm inflow under pumping conditions at MW-C01 at 149 to 152 ft bgs.
- 0.2 gpm inflow under pumping conditions at MW-W02R at 223 ft bgs.

At NE02, because of thick fill/residuum, bedrock was not encountered until 135 ft bgs, and the permanent casing depth is 166 ft bgs. Flows up to 0.48 gpm were measured in the upper part of the boring under ambient conditions before the permanent casing was placed (interpreted inflow of 0.48 gpm). In flowmeter testing after placement of permanent casing, the maximum interpreted flow was 0.06 gpm, under both ambient and pumping conditions.

In summary, the new wells showed little vertical flow in the SPA, with minimal flow below the weathered bedrock (typically around 130 ft depth). As with the private wells, water levels dropped quickly at low pumping rates, suggesting that much of the water pumped was from borehole storage.

3.3.5 Packer Test Results

Packer testing was done to isolate different zones and allow measurement of water pressure (head) in each isolated zone. This information was then used to calculate vertical flow gradients. An important use of packer testing was in crossover wells, where the packer was used to seal off the OCU so that the heads in the SPA and Ozark Aquifer could be measured.

Two types of packer tests were conducted: single and straddle. All packer tests were conducted in crossover wells except for one straddle packer test in Well NE01. In the single packer tests, a single packer (air-filled bladder that seals off part of the borehole) was installed at the Chattanooga Shale to separate the two aquifers. Pressure transducers placed above and below the packer provided pressure measurements within each aquifer. The straddle packer tests were intended to measure the vertical gradient within the SPA. This is important because if there is a significant vertical gradient within the SPA, the head at the bottom of the SPA would be needed to calculate the vertical gradient between the SPA and the Ozark Aquifer. In the straddle packer test, a three-foot interval between two packers was sealed off. This allowed isolation of a small zone to measure pressure only within that zone. This 3-ft zone was intended to be in the lowermost SPA formation, just above the OCU (the Pierson). By measuring the head in the Pierson and in the open hole in the SPA above, the vertical gradient in the SPA could be determined. Packer test results are summarized in Table 3-5; details and graphical results are included in Appendix L. The following general observations can be made:

- The Ozark Aquifer pressure stabilized relatively quickly in all cases.
- The SPA pressure was continuing to rise at the end of all the tests (including at Well A071672, which was extended to 17 hours), except for Well 119, where it stabilized quickly. A relatively long time to stabilize indicates relatively low conductivity. Based on the flowmeter tests and OBIs, slow stabilization was expected in the SPA. The rapid stabilization noted at Well 119 suggests higher conductivity, although nothing observed in the OBI from Well 119 suggests higher conductivity in the SPA in this well. However, unlike the other crossover wells tested, the initial and SPA water levels at Well 119 were both within the cased interval. This high water level found in Well 119 is likely due to its proximity to Hickory Creek and Elm Spring Branch, where the water table is in the alluvium and weathered bedrock, both of which have much higher conductivity than the SPA below the weathered bedrock. The other wells tested are at higher elevations, where the water level is at or below the weathered bedrock. The rapid stabilization observed at Well 119 could have resulted from leakage around the casing, or at least a hydraulic connection between the permeable alluvium/upper weathered bedrock and the well. Among the crossover wells in the Hickory Creek watershed, Well 119 also has the highest TCE detections (Figure 3-6B), indicating potential hydraulic communication between the upper weathered bedrock and the water in the well.
- The three straddle packer tests, which were intended to measure the head in the Pierson Formation, near the bottom of the SPA (in addition to measuring the heads in the SPA and the zone below the bottom packer), indicated that the Pierson is relatively impermeable and probably part of the OCU in the Study Area. As noted in Table 3-5 and detailed in the Colog report in Appendix L, pressures did not dissipate in the intermediate zone of the straddle packer tests, which was located in the Pierson. This is likely indicative of the relative impermeability of the Pierson formation: the inflated packers above and below this measured zone put pressure on the water in this zone; because of the relative impermeability of the zone, the water pressure could not be relieved. In addition, at Well NE01, the bottom packer isolated the zone from 360 to 371 ft, the bottom of the boring, and the pressure was also not dissipated in this interval, which is also in the Pierson.
- Head differences between the SPA and Ozark were estimated for the tests where the response from the SPA did not stabilize (as noted above, this includes all locations except for Well 119). Estimates ranged from 113 to 175 ft of head difference, except at Well A071672, where the estimated head difference was 6 ft. As detailed in the footnote, based on the overall SPA potentiometric surface, this estimated head difference at Well A071672 is likely a significant underestimation of the head difference.[26] In spite of continuing the test for 17 hours, the head in the SPA was still rising steadily at the end of the test, precluding an accurate projection of a final head. At Well 119, where both pressures stabilized quickly, the calculated head difference was 93 ft. Because the SPA is a water table aquifer that is expected to generally reflect surface topography, and the Ozark gradient is generally east to west across the Study Area, head differences would be expected to be greatest at higher elevations in the west part of the Study Area, and least at low elevations in the east part of the Study Area.[27] The results generally reflect this.

In summary, as indicated by the rapid pressure stabilization in the Ozark and the lack of stabilization in the SPA in all wells except Well 119, the conductivity of the Ozark formations within the crossover wells is much higher than the conductivity of the SPA. Higher conductivity at Well 119 may be the results of communication with the higher conductivity alluvium and weathered bedrock at that location. Estimated head differences between the SPA and the Ozark ranged from 93 to 175 ft (not including

[26] Based on the 2015 potentiometric map, the static water level in the SPA at 0A071672 would be expected around elevation 1060 ft (depth bgs = 127 ft). Had the SPA head been at this level, it would have resulted in a 77 ft head difference with the Ozark Aquifer. This is a much more reasonable estimate of the head difference than the calculated 6 ft. As noted in Table 3-5, the water level in the SPA was rising steadily throughout the test, even though the test continued for 17 hours, and a true final level could not be projected. The OBI and flow tests (Section 3.3) suggest very low flow in the SPA within the well.

[27] Note that while the regional Ozark Aquifer gradient is east to west, there may be local variations.

one result where the SPA head was still rising steadily after 17 hours of testing). Straddle packer testing suggests that the Pierson is part of the OCU in the Study Area.

3.3.6 Observations of Water Loss During Drilling - New Wells

Water loss was monitored during drilling as an added indicator of the hydraulic properties in the formations, recognizing that water loss during drilling is a likely indication of zones of higher permeability. Such losses were documented in the boring logs (Appendix D) and estimates of significant zones of water loss are summarized below.

- MW-C01 – 1,400 gallons lost from 0 to 72 ft.
- MW-C02 – 1,000 gallons lost from 0 to 80 ft.
- MW-C03 – 1,900 gallons lost from 0 to 90 ft, drilling original hole on 10/09/14;1,000 gallons lost from 0 to 90 ft on 10/14/14 (reaming). Lost an unspecified amount of grout at 50 ft.
- MW-C04 – 800 gallons lost from 0 to 106 ft.
- MW-NE01 – 2,500 gallons lost from 0 to 90 ft, and “notable” loss at 91 ft.
- MW-NE02 – 1,700 gallons lost from 0 to 165 ft. (Fill/residuum was 135 ft thick at this location.)
- MW-W02 – 650 gallons lost at a fracture zone from 17 to 19 ft.
- MW-W03 – 1,000 gallons lost from 0 to 80 ft.

In summary, all documented water losses occurred in the residuum or upper weathered bedrock, indicating higher permeability in these upper portions of the SPA. Except for Well NE02, where fill/residuum was 135 ft thick and weathered bedrock consequently extended to a greater depth bgs, all documented losses occurred above 106 ft bgs.

3.4 Surface Water Characteristics

As discussed in Section 2.3, the Study Area includes parts of three surface water drainage systems: Hickory Creek to the north and east, Buffalo Creek to the west and Indian Creek to the south. As noted in Section 2.4.1, two dye injection points in the upper Buffalo Creek drainage resulted in dye detections in Big Spring, Hearrell Spring and other smaller springs in the Hickory Creek basin. Based on this finding, the inferred recharge area boundaries shown in Figures 2-6 and other figures in the report were drawn to include the upper Buffalo Creek area in the Hickory Creek drainage. Otherwise, the recharge boundaries are drawn to follow surface drainage divides, determined from the topography shown in Figure 2-6. The QRA lies within the Buffalo Creek Recharge Area, while the MPA, ETA, and CTA are within the Hickory Creek Recharge Area.

Of the three major streams included in the Study Area, Hickory Creek is by far the largest. This is illustrated by the flow data in the Figure 3-3 series (also found in Table 3-6), which shows the results of the quarterly stream and spring flow sampling within the Study Area. The maximum flow rate measured in Hickory Creek, 48 cubic ft per second (cfs), is more than four times the maximum measured in Buffalo Creek. Indian Creek itself is not in the Study Area, only a tributary, Bullskin Creek, with a maximum measured flow rate of 1 cfs. The springs in the Hickory Creek Recharge Area are also much larger than the springs in the Buffalo and Indian Creek recharge areas. Four springs in the Hickory Creek Recharge Area had maximum measured flow rates greater than 10 cfs (Unicorn, Elm, McMahan and Bartholic). The maximum flow measured in a spring in the Buffalo Creek Recharge Area was 0.04 cfs. Only two springs were found in the Indian Creek Recharge Area, with a maximum measured discharge of 2 cfs.

As noted in the Figure 3-3 series and in Table 3-6, streams and springs show significant seasonal variation. For example, Hickory Creek at sampling locations 5 and 6 had discharges of 40 to 50 cfs during the second quarter (spring) of 2013, but dropped down to 6 to 7 cfs in the fourth quarter (fall) of 2013. While the streams typically show lowest discharge in the fall, second lowest in winter and highest in spring or summer (third and fourth quarters), the springs show more variability. For example, at McMahan and Elm Springs, the highest discharge was measured in the winter, while at Unicorn the highest was in summer. While nearly all springs had lowest measured discharge in fall, at Hearrell Spring, the fall discharge was greater than the winter discharge. This greater variability in spring discharge with season is probably due to the springs having a smaller recharge area, and hence being more affected by localized rainfall events.

3.5 VOCs in Groundwater and Surface Water

The most recent TCE detections for all groundwater and surface water samples are included in Appendix O.

3.5.1 Private Water Sampling

The results of private water sampling are included in Appendix E, and TCE results are shown graphically in Figures 3-4, 3-5, and 3-6 (series). In accordance with the Work Plan, private water samples were obtained from spigots located as near as possible to the well and prior to any type of treatment system (if present). TCE is the only COPC that has been detected in private water samples at significant concentrations (i.e. in excess of the federal maximum contaminant level (MCL).[28] All wells where sampling indicated TCE concentrations greater than 5 µg/L are within the areas that are connected to or have been offered connection to the Neosho Public Water Supply, as shown on Figures 3-4 and 3-5. Based on the private water sampling results, the area previously offered city water near the QRA was expanded and ten additional locations were connected to the public water supply system in 2014. This work was implemented as a supplement to the scope of the approved Phase 1 RI Work Plan (URS 2012) as approved by EPA on 13 November 2013. Details of this supplemental activity are documented in a separate report (Haley & Aldrich, Inc., 2014).

Figure 3-4 shows private water TCE results for Phase 1 RI sampling. In addition, for those wells that were sampled prior to the Phase 1 RI, Figure 3-4 shows the most recent TCE result prior to Phase 1 RI. Figure 3-5 shows the same general results, grouped by aquifer, where that information is available, and the Figure 3-6 series shows the specific results by aquifer.

In summary, of the 64 private water sources sampled during the Phase 1 RI, 24 showed detections for TCE. Of these 24, nearly half were from wells known to be completed in the SPA. Of the 9 private water samples for which TCE concentrations were greater than 5 µg/L, 6 were from wells known to be completed in the SPA, and three were from crossover wells. Only two private water sources located in the Ozark Aquifer had TCE detections, and both were below 5 µg/L. One of these was an estimated detection, below the reporting limit. The highest TCE detections were found in SPA wells.

3.5.2 Monitoring Well Sampling

3.5.2.1 New Monitoring Wells

To assess variations in TCE in groundwater with depth within an individual well, samples were obtained at different depths. First, grab samples were collected from the upper part of each of the new wells before the installation of permanent casing.[29] Then, after installation of casing, two rounds of samples were collected using diffusion bags placed at various depths within the boreholes. While use of the diffusion bags is less effective for detecting vertical variation than actual physical separation of groundwater zones, the diffusion bags give some indication of concentration change with depth. The diffusion bags were placed for overall coverage and potential water-bearing fractures (as identified from the OBIs) were targeted. The analytical results for all chemicals detected are included in Appendix E, and TCE results are shown graphically in Figure 3-7.

At MW-NE01, which was installed downgradient of the CTA and between the CTA and the well and spring near Hickory Creek which exhibit the highest TCE detections, TCE was detected at 40 µg/L in upper residuum and weathered bedrock, prior to the installation of permanent casing. As shown in Figure 3-7, detections below the permanent casing ranged from 2 to 8 µg/L, with lower concentrations at greater depths.

At MW-NE02, located northwest of the MPA, TCE was not detected above the detection limit.

In the wells installed to investigate impacts from other potential source areas and/or to assess any westerly impacts from the MPA (MW-C01 through MW-C04), TCE was either not detected or detected at very low levels (≤ 2 µg/L).

At MW-W02/W02R, installed to indicate groundwater impacts south of the QRA, TCE was not detected above the detection limit.

At MW-W03, installed to assess potential impacts within the deeper part of the SPA at the QRA, TCE was detected at 54 µg/L in the grab sample from the upper residuum and weathered bedrock, prior to installation of casing. TCE was not detected at depths below the permanent casing.

[28] 40 CFR 141.61.
[29] This discussion does not include MW-W01, which was a replacement well for a source area well at the QRA.

In summary, of the eight new wells (not including the replacement well MW-W01), TCE was not detected in wells MW-NE02 (northwest of MPA), MW-C02 and -C04 (potential new source area wells), and MW-W02R (south of the QRA). TCE was detected at concentrations of 2 µg/L or below in wells MW-C01 and C03 (potential new source area wells). TCE was detected above 2 µg/L in only two wells: MW-NE01, downgradient of the ETA/CTA and in MW-W03, at the QRA. At MW-NE01, TCE was detected at 40 µg/L in a grab sample taken in the upper residuum and weathered bedrock, prior to the installation of permanent casing. Detections below permanent casing at MW-NE01 ranged from 2 to 8 µg/L. At MW-W03, the grab sample TCE detection before installation of permanent casing was 54 µg/L. TCE was not detected in Well MW-W03 below the depth of the permanent casing.

3.5.2.2 Source Area Wells

Monitoring wells at each of the four known source areas were sampled using either Typhoon® or low flow pumps for comparison to previous sampling events at these locations.[30] The results for chemicals detected in groundwater are included in Appendix E, and results for TCE are shown in figures as follows:

- Figure 3-8 – MPA
- Figure 3-9 – QRA
- Figure 3-10 – CTA
- Figure 3-11 – ETA

The figures show results collected during the Phase 1 RI, and for each well, the most recent result prior to the Phase 1 RI, if available.

For the MPA, results of groundwater samples collected during the Phase 1 RI in 2013 and 2015 were consistent with historical concentrations for most locations, with TCE concentrations ranging from non-detect to 1,200 µg/L. For several locations, TCE concentrations were detected at levels slightly higher than had been previously detected in previous sampling events. Comparison of the sampling results from 2013 and 2015 also indicated significant variability in results at several locations for the two sampling events, for which the 2015 results were lower than the 2013 results. For example, TCE was detected in well MPA-MW021 at 200 µg/L in 2013 and was non-detect in 2015.

For the QRA, results of groundwater samples collected during the Phase 1 RI in 2013 and 2015 were also consistent with historical concentrations, with TCE concentrations ranging from non-detect to 1,100 µg/L. The Phase 1 RI results were similar to concentrations from the most recent results prior to the Phase 1 RI (typically from 2007), but less than the maximum concentrations at all locations, which had generally occurred before removal actions were initiated at the QRA. Comparison of the recent sampling results from 2013 and 2015 indicated significant variability in results at several locations for the two sampling events, for which the 2015 results were lower than the 2013 results. For example, TCE was detected in well QRA-MW002 at 1,100 µg/L in 2013 and 260 µg/L in 2015.

For the CTA, results of groundwater samples collected during the Phase 1 RI in 2013 indicated lower concentrations compared to historic highs at wells closest to the area previously excavated during removal action activities and similar-to-slightly-lower concentrations at other locations, with one well showing higher concentrations. For example, for well CTA-MW010, located adjacent to the former Primary Lagoon area that had been excavated, TCE had historically been detected at concentrations as high as 18,000 µg/L but was detected at 200 µg/L in the 2013 sample. TCE was detected at a higher concentration than past sampling events at well CTA-MW029, with TCE detected in 2013 at 24,000 µg/L.

For the ETA, results of groundwater samples collected during the Phase 1 RI in 2013 were generally consistent with historical concentrations, with lower concentrations indicated at several locations attributed to ongoing effects of past removal action activities. For example, TCE was detected at well ETA-DPE04 in 2013 was 24,000 µg/L compared to a concentration of 127,000 µg/L detected during the previous sampling event in 2005.

In summary, source area well sampling during the Phase 1 RI showed consistent or lower TCE concentrations at source area sampling locations where removal action activities have been completed, compared to historic highs. Higher concentrations were observed at a few locations, corresponding to areas where removal actions are currently being conducted (MPA) or that were outside the areas where past removal action activities were completed (CTA).

[30] Typhoon® pumps were used for the 2013 sampling and low-flow pumps were used for the 2015 sampling.

3.5.3 Springs and Streams

Extensive reconnaissance was performed to identify springs and streams in the Study Area for sampling in addition to previously mapped springs.

Surface water sampling was performed at 19 springs and 14 streams with repeated sampling events at various springs over three years. This sampling included springs and streams identified during previous sampling events and also numerous additional locations identified as a result of the reconnaissance performed for the Phase 1 RI. Results of spring and stream sampling are tabulated in Appendix E and shown in Figure 3-12. The majority of streams and springs showed no detection of TCE. The primary VOC that was detected, if detections were present, was TCE, which was detected at 3 of the 19 sampled springs and 5 of the 14 sampled stream locations. TCE was detected at concentrations above 5 µg/L in Spring 3 (Unicorn) and in Elm Spring Branch and Hickory Creek immediately downstream of Unicorn Spring. The only other detections of TCE in springs and streams were further downstream in Hickory Creek, Spring 6 (Carter), and Spring 17, a very small spring in the upper reaches of Elm Spring Branch.

In summary, TCE was detected at three springs and 5 stream sample locations. The maximum detections are in Unicorn Spring, at 20 to 30 µg/L. None of the detections in the other two springs were above 5 µg/L. All stream detections are downstream of Unicorn Spring in Elm Spring Branch or Hickory Creek, with decreasing concentrations in the downstream direction.

4 Analysis and Conclusions

The results of the literature review detailed in Section 2, combined with the extensive field work conducted during the Phase 1 RI as described in Section 3 form the basis for a refined understanding of the relationship between geologic features and groundwater flow, and the vertical gradients between the SPA and the Ozark Aquifer.

4.1 Geologic Features and Groundwater Flow

The analysis below forms the basis for the conceptual site models presented in Section 5.2. First, the overall framework (structure and stratigraphy) within which groundwater flow occurs is described. Then the narrative follows the path of water moving through the geologic system at the Study Area, beginning with precipitation that falls on the Study Area. Key points in the analysis are as follows:

- The investigation results indicate a consistent geology across the Study Area with continuity of the main stratigraphic units, including the OCU.
- Recharge boundaries are the same as topographic drainage areas, with the exception of a small area at the upstream end of Buffalo Creek, which recharges to Hickory Creek. Source areas are unaffected by this boundary change. Groundwater flow at the source areas remains within the topographic drainage areas: ETA, CTA, and MPA in Hickory Creek and the QRA in Buffalo Creek. Indian Creek is not affected by groundwater from any of the source areas.
- At the sites in the Hickory Creek drainage (ETA, CTA and MPA), most of the recharge flows rapidly through the high conductivity chert zones and weathered bedrock in the upper SPA, exiting at springs.
- At the QRA, in the Buffalo Creek drainage, little infiltration occurs because of the surficial fragipan, and most recharge that does occur flows through the weathered bedrock and exits at springs and streams.
- Typically, significant weathering is limited to the upper 50 ft of bedrock, or to a maximum depth of approximately 130 ft bgs.
- Below the weathered bedrock, the SPA appears to be a very low-producing aquifer.
- The OCU, consisting of multiple formations including the Chattanooga Shale, is continuous across the Study Area, and the permeability is very low.
- The upper part of the Ozark Aquifer appears to produce significantly more groundwater than the SPA.

4.1.1 Structure and Stratigraphy

In assessing groundwater flow, it is important to identify geologic structural features such as faults and folds. Faults offer pathways for groundwater flow, as can tension fractures in folded bedrock. In particular, in an area like the Study Area, where the bedrock consists of fairly flat-lying sedimentary formations, faults with vertical displacement can greatly influence groundwater flow. For example, a fault affecting the horizontal continuity of the OCU would greatly impact flow between the SPA and the Ozark Aquifer.

As discussed in Section 2.1.1 and shown in Figure 2-3, there are no major, regional-scale mapped structural features in the Study Area. The only potential structural features identified in published data are lineaments mapped by Whitfield (1999). The two nearest major faults, the Chesapeake and Greasy Creek, which USGS used as boundaries for their 2010 groundwater flow model (Czarnecki et al 2010, fig 3), lie far from the Study Area and well outside of Newton County.

In addition to the absence of major structural features in the Study Area, published data indicates that the Study Area is comfortably within the area underlain by the OCU, with an estimated thickness of approximately 20 ft (Figure 2-10).

The many OBIs, new wells and published MDNR and USGS well logs analyzed as part of the Phase 1 RI confirm the continuity of the stratigraphy across the Study Area. This is illustrated in the cross sections shown in the Figure 4-1 series. Minor differences in the cross sections, such as the absence of the Warsaw in some places and the high elevation of the top of the Elsey/Reeds Spring on Figure 4-1B are likely the result of interpretation: the Warsaw can be difficult to distinguish from the Burlington-Keokuk in the Study Area (Whitfield 1999), and the Burlington-Keokuk, Elsey and Reeds Spring are all similar-appearing very cherty limestones in the Study Area.

As noted in Section 2.1, Whitfield (1999) mapped lineaments in the Study Area. As the lineaments generally follow the regional bedrock fracture pattern, they are likely surface expressions of minor bedrock fractures. Additional/extended lineaments have been identified downgradient of the ETA, CTA and MPA (shown in Figures 5-2A and 5-2B and discussed in Section 5). Since the stratigraphy does not indicate horizontal displacement of formations, if the lineaments do reflect bedrock fractures, they appear to be fractures without significant displacement (joints). Jointing is typical in limestone bedrock, including limestone bedrock in areas with no other observable structural features.

Most importantly, the data specific to the Study Area confirms the continuity of a key member of the OCU, the Chattanooga Shale (Figures 4-2 and 4-3). As shown in Figure 4-2, the estimated thickness of the Chattanooga Shale in the vicinity of the source areas is approximately 10 to 20 ft; thicker in some wells and as thin as 5 ft in one well-bounded location. In addition, as shown in the contours in Figure 4-3, the top of the Chattanooga Shale is relatively flat and the contours do not suggest folding or faulting. Faulting, if present, could provide preferential flow paths for groundwater, as could tension cracks in folded rock. In the area of Hickory Creek north of the MPA/CTA/ETA, the elevation of the top of the Chattanooga Shale varies, with a slope of approximately 1%. While any variation from horizontal can potentially be related to structure features, the gentle slope of the Chattanooga Shale surface and lack of fit with regional structural features does not suggest structural control.

4.1.2 Groundwater Recharge – the Influence of Surficial Material

Only a fraction of the precipitation that falls within the Study Area boundaries enters the groundwater system. That fraction is variable over the Study Area and highly dependent on the nature of surficial material.

As described in Section 2.2 and illustrated in Figures 2-7 through 2-9, surficial geologic materials in the Study Area have been mapped by geologic origin (Whitfield 1999) and by hydrologic properties (NRCS).

Little recharge would be expected in the areas underlain by cherty residuum with fragipan, which corresponds generally to NRCS Hydrologic Soil Group D. The QRA lies well within the residuum with fragipan soil (Figures 2-8 and 2-9).

The ETA and the CTA both lie partially within the NRCS high conductivity soils (Hydrologic Soil Group A), which connect with the conductive alluvium (Hydrologic Soil Group B) in the Hickory Creek drainage. The MPA is within the fragipan soil type area, but close to a drainageway similar to those at the ETA and CTA. Based on published reports and field observations, these NRCS high conductivity soils appear to consist of coarse chert gravel. Based on these properties and the dye trace results (Section 2.4.1), areas of high conductivity soils and alluvium would be expected to have high recharge. In addition, because they are in drainageways, they likely also receive runoff from the higher fragipan areas.

4.1.3 Groundwater Recharge Boundaries and Lateral Constraints

The dye trace results (Section 2.4.1) together with the distribution of detections of TCE in surface water and groundwater, formed the basis for establishing recharge boundaries for the SPA, and the lateral constraints of those boundaries.

Typically, the potentiometric surface of a water table aquifer such as the SPA is a subdued version of the surface topography. Surface water drainage divides, as expressed by surface topography, also represent groundwater drainage divides. This is not always the case in a karst environment, where subsurface conduits can carry water in pathways unrelated to surface drainage systems.

As discussed in Section 3.4, the inferred recharge boundaries are based on surface drainage divides, as modified by the dye trace results. Of all the dye tracing done in the Study Area, only two, both in upper Buffalo Creek, showed groundwater flow paths that crossed surface water drainage divides. The adjustment to the inferred recharge boundary at upper Buffalo Creek, shown on Figure 2-6 and other figures, reflects the subsurface connection of this area to the Hickory Creek Recharge Area rather than to Buffalo Creek. Note that this boundary is a simplification of actual conditions.

In the Hickory Creek Recharge Area, the dye trace results and the distribution of detections of TCE in surface water and groundwater support the conclusion that flow from the ETA, CTA and MPA is bounded by Elm Spring Branch and Hickory Creek. This is described in detail in Section 5.1.1.

4.1.4 Epikarst Flow

Based on the dye trace results (Section 2.4.1), the hydraulic conductivity property of the flow paths from the ETA, CTA and area near the MPA corresponds to that of a coarse gravel – roughly, on the order of 1E+05 ft/day. These flow rates could indicate small scale karst conduits that may form along joints in the bedrock, and/or coarse gravel (e.g., chert gravel originating from residuum). Based on the dye trace results, NRCS mapping, and surficial geology, these very high-conductivity pathways appear to be associated with localized chert gravel streambeds, alluvium, and small-scale karst features associated with joints.

The rapid discharge to springs and streams is supported by the high variability in flow in springs (Section 3.4). Springs "flash" after heavy rain events and flows decline in periods of low rainfall.

As noted in Section 2.4, published reports state that the groundwater flow direction in the SPA is mostly lateral toward springs and streams. This is consistent with both the inferred hydraulic conductivity values from the dye tracing and the published values used in the USGS model. The lateral flow paths identified by dye tracing have hydraulic conductivity values ranging from approximately 100,000 to one million times greater than the vertical conductivity of the SPA used in the USGS model. This means that, within the SPA, with an equal driving force (head difference) and adequate flow capacity, the lateral flow path would need to 100,000 to one million times longer before the vertical flow path would be preferred.[31]

Note that the ETA, CTA and MPA are at or close to drainageways with alluvium, where the upper reaches of the drainageways have highly conductive material (Figures 2-8 and 2-9). The QRA is located well within residuum with fragipan and is not near drainageways with conductive material (Figure 2-9).

Recharge – A Useful Qualitative Concept

Recharge may be defined as equal to precipitation, less (1) runoff into rivers, (2) direct evaporation, and (3) evapotranspiration or direct interception from plants in the soil zone (Czarnecki et al 2010 p 16). In the Study Area, a large portion of the water that infiltrates into the ground ends up discharging to springs and streams, often in flow paths above the saturated zone (epikarst). That is, the flow seems to meet the definition of recharge, yet it never actually reaches the water table. While it would make sense to exclude this epikarst flow from recharge calculations, quantifying this flow is not possible, as in some instances it is part of the saturated zone instead of merely above it.

The difficulty of attempting to quantify recharge is illustrated by the large range in recharge values developed by investigators using different approaches for areas near the Study Area. Using the water-table fluctuation method (i.e., evaluating the recharge that actually reaches the water table), one group of investigators estimated recharge at 0.9 inches/year (Risser et al 2005, as cited in Czarnecki et al 2010 p 18). Other investigators, evaluating recharge as defined above and based on a detailed analysis of all contributing factors, estimated recharge rates of 5 to 10 inches per year (Dugan and Peckenpaugh 1985). The large differences suggest that much of the "recharge" water leaks out laterally without impacting the static water table. Modelers need to use some value for recharge, so they typically choose a value that, given other boundary conditions, results in a water table elevation that matches observed conditions. Czarnecki et al used a recharge rate of approximately 3 inches per year for the vicinity of the Study Area. (In the Hickory Creek portion of the Study Area, these three inches of recharge can be accounted for in the discharge of springs not included in the Czarnecki model. This is not really meaningful, though, in light of the above discussion on recharge including the method by which the modeled three inches of recharge was arrived at.) A larger or smaller scale model would need to use other recharge rates (Czarnecki et al 2010 pp 17 and 18).

4.1.5 Weathered Bedrock

Weathered bedrock is transitional with cherty residuum at the top and with sound bedrock at the bottom. The depth of weathered bedrock is highly variable, but generally extends to a depth of about 130 ft or less (in most areas investigated, this includes roughly the upper 50 ft of bedrock). In upland areas, the water table is generally found around the depth of weathered bedrock. This suggests that water drains laterally more easily in the weathered bedrock than in the sound bedrock below. The following characteristics of weathered bedrock were observed in the Study Area:

[31] The vertical SPA conductivity values (*k*) used for the area that includes the Study Area in the USGS model were 1E-01 and 3 E-01 ft/day (Czarnecki et al 2010, Table 6). Vandike and Brookshire (1996, p. 12) reported straight line groundwater velocities between the ETA and the Hickory Creek Groundwater Inflow Zone of 1,017 to 2,500 ft/day. (Actual velocities are likely higher since the flow is not likely straight-line.) Using the straight-line gradient (*i*) between the injection and detection points (180 ft/13,000ft = 0.014) and Darcy's Law (velocity = $k * i$) results in a *k* value of approximately 1E+05 ft/day. This is approximately one million times the SPA vertical *k* value used in the USGS model. The range of velocities calculated by Vandike and Brookshire for the CTA were a little less than those for the ETA.

- The weathered bedrock has larger fractures and a higher frequency of open fractures than the sound bedrock. This is based on a review of boring logs from the source areas, observation of OBIs, fracture analysis (Sections 3.3.1 and 3.3.2) and observation of deep rock cuts in a quarry west of the Study Area and in the exposed sidewalls during the CTA excavation (see photos in Appendix H). Fractures appear to be primarily related to bedding planes.
- During installation of the new wells, grout loss and water circulation loss occurred in the weathered bedrock (Section 3.3.6)
- Perched water may be present in the weathered bedrock. This has been observed in the monitoring wells at the source areas, and in the former primary lagoon excavation at the CTA.

4.1.6 Geologic Features in the SPA below the Weathered Bedrock

Below the weathered bedrock, the SPA appears to be a very low-producing aquifer, with little flow compared to the upper zones. This is based on:

- Fracture analysis, which found no significant fractures, no moderate fractures below the upper 30 ft of bedrock, and the majority of the small fractures within the upper 50 ft of bedrock (Sections 3.3.1 and 3.3.2).
- Flowmeter testing, which found only very low flows under both ambient and pumping conditions (Sections 3.3.3 and 3.3.4).
- Visual observation of the OBIs for wells for which fracture analysis was not conducted, which confirmed that conditions were similar to those where fracture analysis was done (Sections 3.3.1 and 3.3.2).
- Rapid reduction in water levels at pumping rates of 1 to 3 gpm, and slow recovery (Section 3.3.3 and 3.3.4).
- Slow recovery following water removal observed during field sampling.
- No loss of water or other fluid below the weathered bedrock during drilling.

Note that these observations indicate much lower flows than reported by Miller and Vandike (Section 2.4). This is likely because Miller and Vandike were reporting very general values intended to encompass the entire SPA, including those relatively chert-free zones with well-developed solution channels. Unlike Robertson et al (1963), who provided values for the Ozark Aquifer, Miller and Vandike did not cite any specific well data. Presumably there are wells within the SPA that produce 30 gpm; however, the data from the Phase 1 RI suggests production rates an order of magnitude less, or even lower. The flows identified during this investigation are consistent with the flow noted by other investigators of less than 20 gpm (Section 2.4).

4.1.7 Geologic Features in the OCU

The OCU is typically considered to comprise the Northview, Compton, Sylamore, and Chattanooga formations, with the Chattanooga the least permeable member (Figure 2-2). These units together make up a thickness of approximately 15 to 30 ft in the Study Area.

During the Phase 1 RI, two samples were obtained from the Chattanooga Shale and subjected to permeability (hydraulic conductivity) testing. The results (Appendix J), converted to ft/day, were 4.0E-06 and 2.2E-06, very similar to those used in the USGS 2010 model (Section 2.4). This data is consistent with what would be expected from a dense shale formation, and are consistent with the assumptions made by others in the USGS model.

Results from the Study Area are consistent with published maps that show the OCU as continuous across the Study Area. In addition, packer test results suggest that the Pierson Formation is likely part of the OCU. Including the Pierson, the OCU thickness is approximately 30 to 50 ft.

4.1.8 Geologic Features in the Ozark Aquifer

The OBIs confirmed the presence of the Cotter and Jefferson City formations, as expected based upon published information (Section 2.1.1). The quick stabilization in the packer tests plus the visual observations in the OBIs appear to be consistent with reported aquifer conditions in the literature. The Cotter and Jefferson City do not appear to be high-yielding, but are certainly higher yielding than the SPA. The reported yields of 20 to 30 gpm (Section 2.4) are consistent with the packer test results. Thin sand units (e.g., Swan Creek sand) may be present (Section 2.4); however, these were not identified on the OBIs.

4.2 Vertical Gradients and Flow between the SPA and the Ozark

Figure 4-4 shows the interpreted potentiometric surface in the SPA, based on data collected in December 2014 and January 2015. The potentiometric surface is typical of a water table aquifer, with groundwater moving laterally toward streams and springs.

Figure 4-5 shows the Ozark potentiometric data collected from the Phase 1 RI, integrated into a small-scale published composite map. The 900-foot contour of the composite map has been adjusted to accommodate the Phase 1 RI data. Phase 1 RI potentiometric elevations for the Ozark ranged from 860 ft amsl at the far west to 995 ft amsl near the center of the Study Area. The depression in the surface at the Neosho city pumping center is apparent, as are depressions at pumping centers at Joplin and Monett. As shown, the general flow direction in the region that includes the Study Area is from east to west, originating from a northeast to southwest ridge in Barry County, located to the east of the Study Area. The available data support only this general flow direction. Additional, larger scale data may indicate local variations in the potentiometric surface.

Based on a comparison of the two figures, the head difference at the QRA may be around 240 ft, while the head difference at the MPA, ETA and CTA may be around 90 ft. [32] The results are generally consistent with the packer test results, where the calculated head differences ranged from approximately 90 to 175 ft.

Using these values and assuming the potentiometric surfaces are constant with depth, using the Chattanooga Shale as a surrogate for the entire OCU, 15 ft as the thickness at the QRA and 10 ft at the other source areas (Figure 4-2), the vertical hydraulic gradient between the two aquifers at the QRA is approximately 16; and at the MPA, ETA and CTA, approximately 9.[33]

These results are on the order of those obtained from published regional data. As noted in Section 2, the regional potentiometric surfaces developed from the USGS study suggest a head difference of approximately 200 ft between the two aquifers in the Study Area (Gillip, Czarnecki and Mugel 2008). Based on this head difference and regional estimates of thickness of the OCU (20 ft, see Figure 2-11) (Imes and Emmett 1994 Figure 34), the estimated vertical gradient between the aquifers is approximately 10. Using the higher of the two permeability test values (4E-06 ft/day), these gradients result in flow rates from the SPA to the Ozark Aquifer of approximately 0.15 in/year for the QRA and 0.09 in/year for the other source areas. Corresponding flow times are 1200 years for the QRA and 1300 years for the other sources areas. The flow rate is comparable to the average 0.2 inches per year for the general location of the Study Area, from the USGS model (Section 2.4.2). The time periods would also be comparable, since the estimates are all based on Darcy's Law.[34]

These estimates are based on the best available data, and would change with different input values. A thinner OCU, greater head, and higher permeability would all results in increased flow and shorter flow times. Because permeability can vary by orders of magnitude, it has the greatest effect. While only two permeability tests were conducted, the results were similar to each other, similar to the values used in the USGS model, and consistent with what would be expected from shale. In any case, the OCU is many orders of magnitude less permeable than the overlying formations. In the USGS model, value used for the horizontal conductivity of the SPA is more than 1 million times the vertical conductivity of the OCU.

Two cases were reported in Miller and Vandike (1997) of documented movement of SPA groundwater to the Ozark in the area where published maps show the OCU as continuous. One is clear-cut, where a contaminated crossover well impacted the City of Republic well, in Greene County Missouri (Miller and Vandike 1997, Figure 39). The other is a case of a dye trace in Barry County, east of Newton County (locations shown in Figures 2-3 and 2-10). Dye was injected into a large sinkhole in the Burlington-Keokuk (SPA) and emerged 6 miles away at Roaring Spring, a large spring in the Cotter/Jefferson City formations (Ozark Aquifer) (Miller and Vandike 1997, p 101). A large fault near the sinkhole, the Greasy Creek Fault, with over 200 ft of offset and vertical separation of the OCU accounts for the dye through the OCU, even though it is mapped as continuous in

[32] Note that the potentiometric surfaces in the two aquifers are based on the simplifying assumption that the potentiometric surface is constant in the vertical direction.

[33] The hydraulic gradient is the head difference divided by the length of the flow path: using the values in the text, the vertical gradient at the QRA is calculated as 240 ft/15 ft = 16; and the vertical gradient at the other source areas is calculated as 90 ft/10 ft = 9.

[34] Darcy's Law: $v = ki$, where v = flow velocity, k = hydraulic conductivity (permeability) and i = hydraulic gradient. Thus, the calculated flow rates in the text are the product of the measured hydraulic conductivity and the gradients, converted from ft/day to inches/year.

this area (see Appendix Q for details). The Greasy Creek Fault may also account for the ridge in the potentiometric surface in Barry County that is the driving force for the westward flow in the Ozark across Newton County (Figure 4-5). The Chattanooga Shale is known to have a jointed structure[35]; however, there are no indications that these joints or other natural features may compromise the integrity of the OCU in or near the Study Area. While through-going vertical fractures have not been observed to exist at the Study Area, if present, they may have the potential to transmit flow from the SPA to the Ozark Aquifer.

In summary, estimated head differences between the SPA and the Ozark Aquifer in the Study Area based on both packer tests and potentiometric maps range from approximately 90 to 240 ft. The calculated vertical gradients between the SPA and the Ozark range from approximately 9 to 16 ft. The calculated flow across the deeper SPA and the OCU in the Study Area, based on available data, is approximately 0.1 to 0.2 inches per year, with a flow time of over 1,000 years. These results are consistent with published data.

While this discussion focuses on the head difference between the SPA and the Ozark, it is important to note that the vertical hydraulic conductivity of the deeper SPA below the depth of weathered bedrock appears to be many orders of magnitude lower than the lateral hydraulic conductivity of the epikarst and weathered bedrock, and therefore very little flow passes vertically through the deeper SPA.

4.3 Potential Impact of Crossover Wells

Some private wells in the Study Area are crossover wells that could provide a manmade conduit for constituents in shallow groundwater to migrate to the Ozark Aquifer. Twenty-three known or potential crossover wells with historical detections of TCE greater than 5 µg/L have been identified in the Study Area (Figure 4-6). Of these, seven are confirmed crossover wells. The chemical results from crossover wells should be understood as representing mostly SPA water, as this water has been flowing down the borehole.

TCE was detected in the Ozark Aquifer from two Ozark wells at very low concentrations: in Well A128870 at an estimated detection of 0.2 µg/L and at Well 194-3 at 0.7 and 0.8 µg/L (Figure 3-6A and Figure 4-7). The estimated detection at A128870 is questionable, as it is based on a single sample with results very close to the detection limit and the well is a 1,600-ft deep high production well in the Potosi formation. However, the detection at Well 194-3 was confirmed by repeated sampling events over two days. A crossover well (194-1) located 300 ft from 194-3 is most likely the source of the detection at 194-3, as it provides a direct conduit to the Ozark Aquifer, and 300 ft could easily be within the range of influence of the pump at 194-3. Historical sample results at 194-1 indicate TCE concentrations of 3 µg/L in 1996 and 1.2 µg/L in 1998. A large-scale map of Wells 194-1 and 194-3 is included in Appendix P.

4.4 Contaminant Trend Analysis

TCE results in most wells have shown declines following removal actions, as detailed below.

4.4.1 Private Water Samples

The Hickory Creek Recharge Area, which includes the MPA, ETA, CTA and downgradient areas, is shown in Figure 4-8 along with select private wells with TCE detections. These wells were selected because they have historical TCE detections greater than 5 µg/L and because they have results from both before and after 2004-2008, when removal actions were performed at the ETA and CTA. As shown in the plots, these wells have shown declines in TCE detections since the completion of removal actions.

Figure 4-9 shows similar results for select private wells near the QRA (Buffalo Creek Recharge Area).

4.4.2 Source Area Monitoring Wells

TCE concentrations, including historical and recent sample results, are plotted for several monitoring wells in each source area in Figures 4-9, 4-10, and 4-11.

[35] Missouri Division of Geological Survey and Water Resources (now Missouri Department of Natural Resources), 1961. *The Stratigraphic Succession in Missouri*. Page 48.

For the QRA, Figure 4-9 indicates that concentrations are generally consistent with historical results across the area, with stable or declining TCE concentrations observed at wells in or near the area addressed by past removal action activities. Notably, Well QRA MW003, which is in the area addressed by the removal action, shows a significant drop in TCE concentration.

For the ETA and CTA, Figure 4-10 demonstrates that TCE concentrations have decreased at various wells since removal actions were initiated, except for well CTA-MW029, which shows an increasing trend. Well CTA-MW029 is an open hole well from 25 to 77 ft bgs located in an area that was not addressed by previous removal actions.

For the MPA, Figure 4-11 indicates there are no definite trends; concentrations have fluctuated and remain within a similar range of concentrations. However, these data were collected before the planned removal action began in 2015. Future results from the MPA would be expected to show similar declining trends as seen in the other source areas after the completion of removal actions.

4.4.3 Other Potential Source Areas

There were several objectives for the installation of wells MW-C01 through MW-C04 (Table 3-1), one of which was to investigate potential new source areas. No TCE was detected in MW-C02 or MW-C04. TCE was detected in very low concentrations in MW-C01 and MW-C03. The results from these wells do not indicate the presence of previously undiscovered source areas.

Based on the results from these wells (Figure 4-12), no further investigation of additional source areas is proposed for inclusion in RI/FS scoping.

5 Conceptual Site Model

Based on the analysis presented in Section 4, the conceptual site model can be summarized as follow:

Most of the recharge that enters the groundwater system in the Study Area is rapidly discharged through the epikarst, which consists of highly permeable chert zones, weathered bedrock and solutioned joints. Most of the hydrogeologic variability among the source areas also occurs within the epikarst. Infiltration of precipitation (recharge) is highly variable across the Study Area and dependent on surface geology and hydrologic soil types. Low recharge and high runoff occur on uplands underlain by fragipan (e.g., the QRA) and high recharge occurs in high conductivity chert zones present at the upstream ends of drainageways (e.g., the ETA and CTA), and in alluvial soils. Flow rates for lateral flow are high in the high-conductivity chert zones, alluvium and associated joints. More dispersed, but significant flow occurs in the weathered bedrock. Most of the recharge discharges to springs and streams within surface water drainages.

Below the weathered bedrock, the CSM is the same for the entire Study Area. Within the SPA below the weathered bedrock, flow is still primarily lateral toward springs and streams; however, as detailed in Section 4, the conductivity within the deeper SPA is many orders of magnitude less than in the epikarst and flows are low. Thus, because of the very high lateral hydraulic conductivity of the epikarst relative to the vertical conductivity of the deeper SPA, relatively little recharge moves below the weathered bedrock. This condition results from the very large difference in the lateral conductivity of the epikarst compared to the vertical conductivity of the deeper SPA, and would be the case regardless of what types of formations lay below the SPA.

However, the OCU lies beneath the deeper SPA and further reduces vertical flow. The OCU is continuous across the Study Area, with hydraulic conductivity values in the Chattanooga Shale many orders of magnitude less than the deeper SPA. Estimated head differences between the SPA and the Ozark range from roughly 100 to 200 ft. Even with these head differences, the very low conductivity of the OCU results in calculated flow through the OCU of approximately 0.1 to 0.2 inch/year, with flow times in excess of 1,000 years.

5.1 Groundwater Flow: Source Area-Specific

Figure 5-1 shows the four historical source areas, along with surface geology and most recent TCE results in private water. This figure shows the overall influence of surface geology on TCE detections in private water. In the Hickory Creek Recharge Area (ETA, CTA and MPA), the highest TCE detections in private water are from wells in the alluvial floodplain of Hickory Creek, some distance from the source areas. At the QRA, private water samples with highest detections are closer to and downgradient of the QRA.

As discussed below in detail, the data strongly suggest that for the source areas in the Hickory Creek Recharge Area, high-volume, rapid, near-surface groundwater flow is associated with a combination of NRCS high conductivity soil/alluvium plus bedding planes and solutioned joints. This allows for rapid transport of VOCs from source areas through discrete pathways to the broad alluvial floodplain of Hickory Creek. The NRCS high conductivity soils and the extensive alluvium in Hickory Creek probably contribute most to these near surface groundwater flows. Lineaments, suggestive of solutioned joints, are present in all three drainage areas (Figure 2-4); however, as shown in Figure 2-9, NRCS high conductivity soils and alluvium are extensive in the Hickory Creek area, and likely contribute to the much larger springs in the Hickory Creek watershed compared to Buffalo or Indian Creek (Section 3.4). Additional near-surface flow passes through the relatively closely spaced fractures of the weathered bedrock. Based on the OBIs, the fractures in the weathered bedrock are primarily associated with bedding planes. Fairly closely spaced joints also provide flow paths, since there is a vertical component of flow. Dispersed, closely spaced vertical fractures in the weathered bedrock can be seen in the quarry photos in Appendix H. These common vertical fractures in the weathered bedrock, which provide for dispersed flow, are distinct from the possible solutioned joints expressed by lineaments, where more discrete flow may occur. While groundwater elevation data suggests that the weathered bedrock is part of the epikarst, flow is much more dispersed throughout the weathered bedrock, compared to the discrete conduits and channels of the NRCS high conductivity soil and the alluvium.

At the QRA, the NRCS high conductivity soil/alluvium is not present, there are no apparent nearby prominent solutioned joints in the bedrock, and near-surface flow appears to be limited to the dispersed flow in the weathered bedrock. In addition, the fragipan at the QRA limits recharge.

The following sections describe near-surface groundwater flow for each of the source areas in detail.

5.1.1 CTA and ETA

Figure 5-2A combines the private water TCE results, surface geology, NRCS Hydrologic Soil Group A (high conductivity chert zones), and dye trace results. At the relatively large scale of Figure 5-2A, it appears that the ETA dye injection points were located in the high conductivity chert zones at the upstream ends of the drainages, and the dye likely traveled to the Hickory Creek alluvium through the high conductivity chert zones and associated alluvial materials. Flow from the ETA to Unicorn Spring is likely also related to jointing. Additional lineaments have been identified – possibly joints – that may provide a pathway from the high conductivity chert zone/alluvium downstream of the ETA to the alluvium near Unicorn Spring. Note that the high conductivity chert zones sometimes align with lineaments, for example, the northeast-southwest trending lineament at the bottom of Figure 5-2A. Hickory Creek itself parallels the northwest-southeast trending lineament, as shown in Figure 2-4, and may be following a joint in this area. Unicorn Spring may be associated with the juncture of multiple joints in this area.

Similar pathways – along high conductivity soil/alluvium and joints – are likely for the CTA, along Elm Spring Branch. The conclusion that dye injection points at the CTA and ETA were in the high conductivity soil are supported by observations of the material at the time of the injections (described in Section 2.4.1).

Note that the dye trace lines are not intended to indicate flow paths; they are merely visual aids to connect injection and detection points. The high conductivity chert zones/alluvium and joints are the most obvious potential flow pathways for the dye injected at the ETA and CTA.

Based on the characteristics of the weathered bedrock and the TCE results from Well MW-NE01, more dispersed groundwater flow travels through the weathered bedrock in the entire area downgradient of the ETA and the CTA. As discussed elsewhere, flow is bounded by Hickory Creek. [36] As described above, more conduit-like flow paths may exist and connect to Unicorn Spring; however, they also appear to be limited to near-surface zones, based on the Hickory Creek bounding.

The TCE detection of 40 µg/L in the weathered bedrock in the upper part of Well NE-01, and the much lower detections below the depth of permanent casing (Figure 3-7), also support the model of dominant flow in the upper geologic units.

5.1.2 MPA

The situation is somewhat similar at the MPA, where dye traces emerge in springs in the Hickory Creek alluvium (Figure 5-2B). However, unlike the ETA and CTA, the MPA is in the fragipan area and not immediately adjacent to high-conductivity zones; therefore, the type of near-surface groundwater flushing action present at the ETA and CTA is not dominant at the MPA. Dye trace results and detections in a nearby spring suggest flow paths similar to those at the ETA and CTA (i.e., in high conductivity soil, alluvium, joints, and more dispersed flow in weathered bedrock).

One possible joint, represented by a lineament, may be influencing shallow groundwater flow at the MPA. The lineament of interest is at the west side of Figure 5-2B, and trending northeast-southwest. Based on the topography shown in Figure 5-2B, this lineament has been extended to the northeast; this extended lineament intersects one of the dye detection stations for 97-02. Note the drainageway west of the MPA with the high-conductivity material and the 97-02 injection point at the upstream end. This drainageway leads to Hearrell Spring (near the top of the figure). However, the dye from the 97-02 injection was not detected at Hearrell Spring. It was detected at three other locations within the Hickory Creek alluvium (including the point that intersects the extended lineament), over 3,000 ft east of Hearrell Spring. However, dye injected at 96-16, another station in the same drainageway that leads to Hearrell Spring, but downstream of 97-02, was detected at Hearrell Spring, but not at any of

[36] As discussed in Section 2.4.1, extensive dye trace results support Hickory Creek/Elm Spring Branch alluvium as bounds on flow from the ETA, CTA and MPA. Private water results also support this (Figure 5-1), including historic results. In the historic data, however, two cases of TCE detections in the uplands just beyond Hickory Creek were identified: Wells 711 and 712, shown in Figure 5-1. (Well 711 is just inside the Study Area boundary, immediately west of Elm Spring Branch and south of Hickory Creek, near the confluence of these streams. Well 712 is approximately 2,500 ft northeast of Well 711.) These wells had reported detections of 0.1 and 0.06 µg/L, respectively, in the 1997 sampling event. These are very low detections, almost surely qualified as they are very close to limits of detection. In six subsequent sampling events at these wells (‘98, ‘00, ‘01, ‘02, ‘03 and ‘04), TCE was not detected. Based on these results, the initial detections were very likely the result of cross contamination or laboratory error.

the 97-02 detection stations. Thus, the dye injected at 97-02 is not following the drainageway as might be expected, but the dye injected at 96-16 appears to be following the drainageway. The cause of the change in flow path between these two injection points may be a northeast-southwest trending solutioned joint, represented by the lineament. The shallow groundwater flow from 97-02 may follow the high conductivity soil in the drainageway until it reaches the joint, which is also approximately where the high conductivity soil reaches its downstream limit. The private water detections of TCE, all less than 5 µg/L, appear to roughly parallel the lineament, further suggesting joint control in this area. While high conductivity soil/alluvium, joints and weathered bedrock are likely the major shallow groundwater pathways at the MPA, COPC migration appears to be limited. TCE detections at only one surface water location, Carter Spring, are likely attributable to the MPA.[37] (Carter Spring is in the general area of the detection points for 97-02; one of the detection points is Carter Spring Branch.) The maximum TCE detection in five sampling events at Carter Spring was 3 µg/L, and TCE was non-detect in all samples from Well NE-02, which was installed within 1,000 ft of the lineament discussed above, and a few hundred feet from the high conductivity material downstream of the 97-02 injection (but upgradient of both).

In summary, the same near-surface flow paths appear to be available near the MPA as at the ETA and CTA; however, flow from the MPA appears to be slower. This is likely because, while the MPA is close to these pathways, it is underlain by fragipan, which reduces infiltration.

5.1.3 QRA

The closest dye traces to the QRA are approximately a mile away, and the QRA is not near any high conductivity soil or alluvium (Figure 5-2C). Based on spring, stream, and well analytical results, the QRA does not appear to impact streams or springs, including the streams with dye traces shown in Figure 5-2C. As shown in the figure, impacted private water appears to be limited to the area downgradient (to the west) of the QRA. While there are no private water results immediately north of the QRA and only one to the east, groundwater impacts are bounded by QRA source area monitoring wells to the north and east (Figure 3-9).

The two dye traces in upper Buffalo Creek (11-02 and CC-7) show the most characteristic karst features of any of the dye traces in that the flow pathways pass beneath the Buffalo Creek drainage and emerge at springs in the Hickory Creek drainage. However, this flow does not appear to be related to or affected by any of the source areas.

Impacts from the QRA are more limited in lateral extent than the other source areas, likely primarily because the QRA is underlain by fragipan and has no nearby high conductivity near-surface material.

The TCE detection of 54 µg/L in the upper part of Well W03 and the non-detects in all samples below the depth of permanent casing (Figure 3-7) support the model of dominant flow in the upper geologic units, in this case, dispersed flow in the weathered bedrock.

5.2 Conceptual Site Model (CSM) Profiles

The CSM profile for the source areas in the Hickory Creek Recharge Area is shown on Figure 5-3, and the CSM profile for the QRA, located in the Buffalo Creek Recharge Area, is shown in Figure 5-4. In both cases, the stratigraphy is relatively flat-lying with the carbonate SPA separated from the carbonate Ozark Aquifer by the OCU. In both cases, the limestone Warsaw formation underlies the upland areas (where all the source areas are located) and the limestone Burlington-Keokuk underlies the stream valleys. These two formations are similar; however Whitfield (1999) notes that the Burlington-Keokuk is jointed. In both cases, the upper part of the bedrock is weathered and the surface is covered with cherty residuum derived from the weathered bedrock.

As shown in the figures, both the weathered bedrock and the cherty residuum are much thinner in the QRA area.

5.3 CSM Flow

The CSM flow profile for the source areas in the Hickory Creek Recharge Area is shown in Figure 5-5, and the CSM flow profile for the QRA is shown in Figure 5-6. Near-surface flow – from the ground surface to the bottom of the weathered bedrock – is discussed in detail above for each of the source areas. The great majority of the flow occurs in these upper

[37] It is possible that the TCE detections at Carter Spring originated from the CTA as one dye trace from the CTA, 99-03, was detected in Carter Spring Branch (Aley 2000).

zones. In the Hickory Creek Recharge Area, the NRCS high conductivity chert zones within the residuum allow for rapid transport of recharge water to the permeable alluvium of Hickory Creek. Near-surface flow likely also occurs along joints in the weathered bedrock, with more dispersed flow generally throughout the weathered bedrock. At the QRA, flow occurs primarily in the weathered bedrock, as the high-conductivity chert zones are not present. Flow likely occurs along dispersed pathways associated with bedding planes and joints in the weathered bedrock. In both cases, the majority of the flow occurs in the epikarst, above the water table. In both figures, the solid blue color below the water table symbols indicates saturation, while the white patches in the epikarst indicate that this zone is typically not saturated.

As summarized in Figures 5-5 and 5-6, flow below the weathered bedrock is the same for the different areas. As described in detail in Section 4, relatively little recharge moves below the weathered bedrock in the SPA. In this zone, there are few open fractures, little measured flow, and slow well recovery after pumping. Although there is a significant head difference between the SPA and the Ozark, minimal recharge passes through the deeper SPA and the OCU because of the very low conductivity of the deeper SPA and the OCU, especially the Chattanooga Shale, the most impermeable member of the OCU. As discussed in Section 4.2, the regional flow direction in the Ozark Aquifer, based on published data, is east to west.

6 Further RI/FS Recommendations

The Phase 1 RI provided sufficient information to scope and perform the next phase of work: the RI/FS. The RI/FS Study Area would be defined as two focus areas: 1) the Northeast Focus Area, which includes the ETA/CTA/MPA source areas and areas downgradient, and 2) the West Focus Area, which includes the QRA source area and areas downgradient. The Northeast Focus Area would be within the Hickory Creek Recharge Area, largely bounded by Elm Spring Branch to the east and Hickory Creek to the north. The West Focus Area would be within the Buffalo Creek Recharge Area. The Indian Creek Recharge Area does not need to be included in the scope of the RI/FS because it is not affected by groundwater from the source areas. Extensive data from wells, dye traces and spring and stream samples indicates that SPA groundwater flow from the ETA, CTA and MPA remains in the Hickory Creek Recharge Area. While there is less certainty regarding the exact location of the boundary between the Hickory and Buffalo Creek Recharge Areas in the vicinity of Upper Buffalo Creek, available data strongly suggests that SPA groundwater flow from the QRA remains in the Buffalo Creek Recharge Area. No detections of TCE have been found in the Indian Creek Recharge Area.

The proposed focus areas are shown in Figure 6-1, with a smaller scale version in Figure 6-2.The boundaries encompass both private water and monitoring well results with TCE detections > 5 µg/L, including historic detections. Historic detections are included because some private wells with TCE detection > 5 µg/L were not sampled in the Phase 1 RI. The boundaries also include stream segments and springs with any detections of TCE during the Phase 1 RI. Because the Phase 1 RI stream/spring data are much more robust than historic data, historic data is not included.

Recommendations for the RI/FS scope of work include:

- Further characterization of the extent of contamination at the identified source areas, including lateral extent of remaining areas of elevated VOC concentrations. This would also include establishing the vertical extent of VOC impact in the SPA in the vicinity of highest shallow TCE groundwater detections at source areas.
- Evaluation of existing data and potential collection of additional data to assess plume stability, including potential for migration of constituents outside of the focus areas.
- Additional evaluation of the Ozark Aquifer to confirm the conceptual site model.
- Further monitoring of groundwater and surface water from springs and streams within the focus areas to update site data.
- Evaluation of existing monitoring wells. The RI/FS should address the most efficient and effective means for long-term monitoring, including use of surface water monitoring and optimization of groundwater monitoring.
- Assessment of vapor intrusion potential in areas impacted by TCE in groundwater.
- Human health risk assessment to evaluate potential exposure to VOCs in surface water and indoor air (from vapor intrusion); and potential exposure to VOCs with the current use of wells with elevated TCE: dermal contact, inhalation and incidental ingestion.
- Consideration of a screening level ecological risk assessment to address potential impacts to ecological receptors. VOC detections in surface water are low enough that a screening level assessment may be sufficient.
- Feasibility study of remedial alternatives.

7 Assumptions and Limitations

The analysis presented in this report is based in part on information provided by others and on publicly available published information.[38] AECOM has referenced/presented this information in this report, but has not independently verified this information.

The conceptual site model represents the current understanding of observed conditions, in the context of the available relevant scientific studies and data collected. It should be viewed as a generalized working model, subject to change based on new information.

[38] All analytical results prior to 2013 were accessed by AECOM from Boeing's database.

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Tables

Table 1-1:
Completed Activities
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Activity	Date		Completed
Televiewer (OBI)[1]	December/January	2012/2013	28 Wells
	October/December	2014	9 Wells
Geophysical Surveys Gamma, Caliper, and Dual Induction surveys	December/January	2012/2013	12 Wells
Flowmeter Testing	October - December	2014	9 Wells
Low Flow Event	October - November	2012	2 Springs 2 Streams
High Flow Event	April/May	2013	2 Springs 2 Streams
Quarterly Spring Sampling[2]			
First Quarter	February	2013	10 Springs
Second Quarter	May	2013	13 Springs
Third Quarter	August	2013	13 Springs
Fourth Quarter	November	2013	11 Springs
Supplemental Event	January	2015	19 Springs
Quarterly Stream Sampling[3]			
First Quarter	February	2013	10 Streams
Second Quarter	May	2013	14 Streams
Third Quarter	August	2013	14 Streams
Fourth Quarter	November	2013	11 Streams
Supplemental Event	January	2015	11 Streams
Quarterly Well Gauging[4]			
First Quarter	February	2013	95 Wells
Second Quarter	May	2013	96 Wells
Third Quarter	August	2013	93 Wells
Fourth Quarter	November	2013	96 Wells
Supplemental Event	April	2014	103 Wells
Supplemental Event	January	2015	86 Wells

Table 1-1:
Completed Activities
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Activity	Date		Completed
Source Area Sampling			
ETA	March/April	2013	13 Wells
CTA	March	2013	11 Wells
MPA	April	2013	14 Wells
MPA	January	2015	4 Wells
QRA	April	2013	8 Wells
QRA[5]	January	2015	12 Wells
Private Water Sampling			
First Event	April/May	2013	52 Wells
Second Event[6]	September	2013	58 Wells
Supplemental Event	May/August	2013	10 Wells
Supplemental Event	October/December	2014	8 Wells
Supplemental Event	January	2015	2 Wells
Supplemental Event	September	2015	1 Well
Monitoring Well Installation[7]	October/December	2014	9 Wells
Monitoring Well Sampling			
Sampling during Well Installation	October	2014	8 Wells
Diffusion Bag Sampling	Early February	2015	8 Wells
Diffusion Bag Sampling	Late February	2015	8 Wells
Packer Testing	December	2014	5 Wells

1. Gamma surveys were done in a portion of the wells during the OBI surveys.
2. Additional springs were added as they were identified. A few springs could not be sampled because they were dry or due to access issues.
3. Additional stream locations were added during Phase 1. A few streams could not be sampled because they were dry or due to access issues.
4. Pumping wells were removed from the gauging list in quarters 2-4.
5. 13 wells were planned for sampling at the QRA; however, Well MW010 could not be located.
6. Includes additional wells in the PWS area.
7. Does not include Well W02, which was abandoned after installation and replaced with W02R.

Table 3-1:
Objectives and Rationales for New Monitoring Wells
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Objectives									
Well Designation	Further refine the understanding of distribution of Chemicals of Potential Concern (COPC)	Evaluate the presence of groundwater flow boundaries	Evaluate the presence or absence of COPC in portions of the site not known to be source areas	Confirm impacts from the QRA are confined to Buffalo Creek Recharge Area	Evaluate whether COPC are impacting or may impact the Ozark Aquifer	Evaluate groundwater flow and COPC distribution between surface water bodies and groundwater concurrently	Evaluate geologic characteristics and flow parameters within the Springfield Plateau Aquifer	Rationale for Field Activities
Northeast Focus Area								
MW-NE01	X				X	X	X	• Located downgradient of CTA. • Determine vertical extent of TCE impact in the Springfield Plateau Aquifer. • Define vertical gradients and zones of higher hydraulic conductivity. • Identify vertical gradients using Corehole Dynamic Flowmeter to identify the groundwater flow zones in the Springfield Plateau Aquifer. • Located between the CTA and the private well with the highest TCE concentration in groundwater (Well #119) as well as the spring (Unicorn Creek) with the highest TCE concentration in a surface water body. • Well has the upper portion of the Springfield Plateau Aquifer open for flow tests of both the conduit and diffuse flow zones.
MW-NE02	X	X				X	X	• Located west-northwest of MPA in the general area where dye trace studies indicate groundwater flow appears to turn more north toward downtown Neosho. • Evaluate impacts northwest of monitoring well MPA-MW018, which is impacted with TCE. • Evaluate the westerly component of groundwater flow which is present at the MPA in groundwater monitoring reports. • Drilled in a location proposed to assist in the identification of the southwest boundary of the Northeast Focus Area. • Well downgradient of MPA, has the upper portion of the Springfield Plateau Aquifer open for observation using OBI surveys of both the conduit (identified in dye trace studies) and diffuse flow zones.

Table 3-1:
Objectives and Rationales for New Monitoring Wells
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Objectives								
Well Designation	Further refine the understanding of distribution of Chemicals of Potential Concern (COPC)	Evaluate the presence of groundwater flow boundaries	Evaluate the presence or absence of COPC in portions of the site not known to be source areas	Confirm impacts from the QRA are confined to Buffalo Creek Recharge Area	Evaluate whether COPC are impacting or may impact the Ozark Aquifer	Evaluate groundwater flow and COPC distribution between surface water bodies and groundwater concurrently	Evaluate geologic characteristics and flow parameters within the Springfield Plateau Aquifer	Rationale for Field Activities
Central Focus Area								
MW-C01			X			X	X	• Located in a predominant groundwater flow direction of the Springfield Plateau Aquifer from MPA. • Well has the upper portion of the Springfield Plateau Aquifer open for observation using OBI surveys of both the conduit and diffuse flow zones. • Advanced to access the horizontal impact of groundwater southwest of MPA-MW017 which has the highest concentrations of TCE related to site. • Advanced to assist in the identification of the south boundary of the Northeast Focus Area. • Located in the vicinity of the Neosho industrial park.
MW-C02			X			X	X	• Drilled south of main industrial area to determine if there are impacts in this area. • Well has the upper portion of the Springfield Plateau Aquifer open for observation using OBI surveys of both the conduit and diffuse flow zones.
MW-C03			X			X	X	• Located on the west side of the main industrial area to determine if there are any VOC impacts. • Advanced to the west to determine if flow in the Springfield Plateau Aquifer is westerly, similar to flow the upland source areas (MPA and QRA). • Well has the upper portion of the Springfield Plateau Aquifer open for observation using OBI surveys of both the conduit and diffuse flow zones.
MW-C04			X			X	X	• Drilled between the main industrial area and private Well A041705 which has had low level TCE detections. • Determine if there is a component of groundwater flow from this area to the dye injection points noted west of MPA during previous work in the area. • Well that has the upper portion of the Springfield Plateau Aquifer open for observation using OBI surveys of both the conduit and diffuse flow zones.

Table 3-1:
Objectives and Rationales for New Monitoring Wells
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Objectives								
Well Designation	Further refine the understanding of distribution of Chemicals of Potential Concern (COPC)	Evaluate the presence of groundwater flow boundaries	Evaluate the presence or absence of COPC in portions of the site not known to be source areas	Confirm impacts from the QRA are confined to Buffalo Creek Recharge Area	Evaluate whether COPC are impacting or may impact the Ozark Aquifer	Evaluate groundwater flow and COPC distribution between surface water bodies and groundwater concurrently	Evaluate geologic characteristics and flow parameters within the Springfield Plateau Aquifer	Rationale for Field Activities
West Focus Area								
MW-W01	X					X	X	• Advanced to evaluate groundwater flow in the area of the QRA site. Past measurements indicate that this location is upgradient of QRA. • Drilled to evaluate the presence or absence of impacts to groundwater northeast of QRA. • Replacement monitoring well for a well previously destroyed or abandoned (QRA-MW013).
MW-W02	X			X		X	X	• Located cross gradient of QRA. • Advanced to assist in the identification of the south boundary of the West Focus Area. • Advanced to evaluate the deeper portions of the Springfield Plateau Aquifer in relation to the shallow QRA monitoring wells in the area. • Well has the upper portion of the Springfield Plateau Aquifer open for flow tests of both the conduit and diffuse flow zones. • Located in the vicinity of private well 2A which had the groundwater sample with the highest TCE impacts for samples collected during the Phase 1 RI.
MW-W03	X					X	X	• Drilled northwest of QRA and nested with QRA-MW006. • Drilled to evaluate the potential for TCE impacts in deeper portions of the Springfield Plateau Aquifer. • Advanced to assist in the identification of subsurface features noted during a former surface geophysical survey. • Well that will have the upper portion of the Springfield Plateau Aquifer open for observation using OBI surveys of both the conduit and diffuse flow zones.

Table 3-2:
Summary of Monitoring Wells Installed in Phase 1 RI
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Well	Date Installed/Grouted Permanent Casing	Depth to Competent Bedrock, ft. bgs[2]	Depth to Bottom of Permanent Casing, ft. bgs	Total Depth, ft. bgs	Surface Elevation, ft. AMSL	Elevation of Bedrock, ft. AMSL	Elevation of Bottom of Casing, ft. AMSL	Bottom of Well Elevation, ft. AMSL
MW-NE01	11/11/2014	68.4	99.5	371	1225.90	1157.50	1126.4	854.9
MW-NE02	12/4/2014	135.5	166	230	1205.46	1069.96	1039.46	975.46
MW-C01	11/24/2014	71.9	103	163	1247.00	1175.10	1144.00	1084
MW-C02	12/6/2014	26.0	80	140	1227.91	1201.91	1147.91	1087.91
MW-C03	11/26/2014	60.0	90.5	164.5	1249.90	1189.90	1159.40	1085.4
MW-C04	12/9/2014	75.5	106	166	1245.71	1170.21	1139.71	1079.71
MW-W01	12/6/2014	30	35	55	1253.42	1223.42	1218.42	1198.42
MW-W02[1]	1/5/2015	19.0	80	80	1235.45	1216.45	N/A	1155.45
MW-W02R	12/21/2014	19	80	240	1236.98	1217.98	1156.98	996.98
MW-W03	11/21/2014	16.0	80	250	1246.48	1230.48	1166.48	996.48

[1]MW-W02 was abandoned on 1/5/15 and replaced by MW-W02R.

[2]In drilling the borings, there was typically a fairly discrete location where the resistance to drilling changed noticeably from “soft” to “hard.” This was the point at which coring would have begun. In some cases, it was top of bedrock. Refer to the boring logs for more information.

Notes:

bgs = Below Ground Surface

AMSL = Above Mean Sea Level

Table 3-3:
Summary of Fracture Analysis Results
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Well	Depths Analyzed (ft bgs)	# of Rank 0 Fractures	# of Rank 1 Fractures	# of Rank 2 Fractures	# of Rank 3 Fractures	# of Rank 4 Fractures	# of Rank 5 Fractures	Depths of fractures Rank 2 or Above (ft bgs)
623	92 - 525 ft	433	212	11	0	0	0	Rank 2 - 106.8 ft Rank 2 - 109.9 ft Rank 2 - 110.5 ft Rank 2 - 112.6 ft Rank 2 - 131.6 ft Rank 2 - 134.8 ft Rank 2 - 136.7 ft Rank 2 - 299.0 ft Rank 2 - 304.0 ft Rank 2 - 325.5 ft Rank 2 - 460.3 ft
C01	65 - 103 ft 95 - 161 ft	42	21	1	0	0	0	Rank 2 - 114.4 ft
C02	57 - 79 ft 74 - 139 ft	104	1	2	0	0	0	Rank 2 - 62.9 ft Rank 2 - 68.8 ft
C03	60 - 88 ft 82 - 165 ft	81	9	4	2	0	0	Rank 2 - 69.5 ft Rank 2 - 72.8 ft Rank 2 - 80.7 ft Rank 2 - 90.8 ft Rank 3 - 71.3 ft Rank 3 - 71.7 ft

Table 3-3:
Summary of Fracture Analysis Results
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Well	Depths Analyzed (ft bgs)	# of Rank 0 Fractures	# of Rank 1 Fractures	# of Rank 2 Fractures	# of Rank 3 Fractures	# of Rank 4 Fractures	# of Rank 5 Fractures	Depths of fractures Rank 2 or Above (ft bgs)
C04	77 - 106 ft 95 - 167 ft	63	18	9	1	0	0	Rank 2 - 88.8 ft Rank 2 - 89.0 ft Rank 2 - 107.2 ft Rank 2 - 108.9 ft Rank 2 - 114.4 ft Rank 2 - 121.2 ft Rank 2 - 147.6 ft Rank 2 - 155.6 ft Rank 2 - 155.8 ft Rank 3 - 106.5 ft
NE01	65 - 99 ft 90 - 371 ft	395	16	2	0	0	0	Rank 2 - 81.1 ft Rank 2 - 99.0 ft
NE02	136 - 168 ft 160 - 229 ft	86	5	11	4	0	0	Rank 2 - 144.0 ft Rank 2 - 148.4 ft Rank 2 - 148.5 ft Rank 2 - 149.9 ft Rank 2 - 150.2 ft Rank 2 - 155.0 ft Rank 2 - 155.2 ft Rank 2 - 163.6 ft Rank 2 - 164.2 ft Rank 2 - 165.0 ft Rank 2 - 166.3 ft Rank 3 - 141.7 ft Rank 3 - 153.3 ft Rank 3 - 163.0 ft Rank 3 - 163.4 ft

Table 3-3:
Summary of Fracture Analysis Results
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Well	Depths Analyzed (ft bgs)	# of Rank 0 Fractures	# of Rank 1 Fractures	# of Rank 2 Fractures	# of Rank 3 Fractures	# of Rank 4 Fractures	# of Rank 5 Fractures	Depths of fractures Rank 2 or Above (ft bgs)
W02	15 - 66 ft 60 - 75 ft	40	35	7	0	0	0	Rank 2 - 32.9 ft Rank 2 - 49.0 ft Rank 2 - 58.6 ft Rank 2 - 61.3 ft Rank 2 - 63.1 ft Rank 2 - 67.1 ft Rank 2 - 67.4 ft
W02R	78 - 240 ft	240	7	1	0	0	0	Rank 2 - 80.1 ft
W03	17 - 79 ft 75 - 250 ft	255	21	4	0	0	0	Rank 2 - 24.8 ft Rank 2 - 38.3 ft Rank 2 - 80.3 ft Rank 2 - 84.9 ft

Notes:

1. bgs = below ground surface
2. See Appendix N for additional data on fracture results.

3. Fracture Ranking Definitions:
Rank 0 – non-flow feature – sealed
Rank 1 – weak feature – partially open crack
Rank 2 – clean, distinct feature – continuous open crack
Rank 3 – distinct feature with apparent aperture – wide open crack or cracks
Rank 4 – very distinct, wide, possible interconnected fracture
Rank 5 – major fracture zone with large openings

Table 3-4:
Summary of Flowmeter Test Results
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Well	Well Depth, ft	Casing Depth, ft bgs	Test Date	Ambient Water Level During Testing, ft bgs	Ambient Test Interval, ft bgs	Ambient Test: Inflow Measurements	Ambient Test: Outflow Measurements	Ambient Flow From SPA to Ozark	Extraction Test: Pumping Rate	Pump Level, ft bgs	Extraction Test: Change in Water Level	Extraction Test Interval, ft bgs	Extraction Test: Inflow Measurements	Extraction Test: Outflow Measurements	Extraction Flow From SPA to Ozark	Relevant Section/ Figure in IDS Report (Appendix L)	Notes on Test
623	603	99	21-Oct-14	298	300-408.5	0.48 gpm @ 99-299 ft 0.02 gpm @ 304 ft 0.09 @ 367-368 ft	0.04 gpm @ 311-313 ft 0.05 gpm @ 325 ft 0.49 gpm @ 408.5-524.2 ft	0.49 gpm	N/A	N/A	N/A	N/A	N/A	N/A	N/A	pp. 20-21	Field crew concluded that the well would not sustain sufficient flow for a flow test under pumping conditions.
A035143	427	119	20-Oct-14	130	130-372	0.02 gpm @ 247.5-249.5 ft 0.21 gpm @ 350.7 ft 0.03 gpm @ 365-372 ft	0.26 gpm @ 372-421.9 ft	0.26 gpm	3 gpm	233	1.7 ft/min	245-372	0.03 gpm @ 247.1-249.5 ft 0.04 gpm @ 365-372 ft	0.04 gpm @ 372-421.9 ft	0.04 gpm	pp. 98-99	Nearly all of the flow coming out of the pump during the extraction test came from a combination of wellbore storage and the fractures above the pump that cannot be tested with the CDFM due to space-restrictions in the wellbore. As such, no test stations could be acquired above 245 feet during pumping.The decrease in inflow and outflow in the extraction test may have resulted from the decrease in head caused by the pumping. In addition, based on the packer test results (Table 3-5) the pump was below the potentiometric surface of the Ozark. Once the SPA head was drawn down by pumping, the pump was supplied by the head in the Ozark, and therefore the measured outflow was minimal.
A071672	449	82	15-Oct-14	213	218-323	0.03 gpm @ 219.7-219.9 ft 0.02 gpm @ 228.6-228.9 ft 0.02 gpm @ 250.7-250.8 ft 0.02 gpm @ 262 ft	0.12 gpm @ 323-444.4 ft	0.12 gpm	3.3 gpm	245	2 ft/min	262-449	0.31 gpm @ 279-311 ft 0.17 gpm @ 323-444.4 ft	0.23 gpm @ 273 ft	minimal	pp. 105-106	Based on the packer test results (Table 3-5), the Ozark potentiometric surface was at a depth of approximately 204 ft bgs, well above the pump level. Flow from the Ozark likely accounts for the upflow (inflow) measurement below the pump level of 0.17 gpm recorded in the extraction testing
A088918	474	83	18-Oct-14	169	192-413	minimal (see note)	minimal (see note)	minimal (see note)	3 gpm	210, then lowered to 260	1.2 ft/min	329-413	minimal (see note)	minimal (see note)	minimal (see note)	pp. 110-112	The results from the testing are qualitative as a result of calibration issues (details in IDS report in Appendix L). Testers concluded the water removed during the extraction test was from borehole storage and that inflow was insignificant. Based on the general potentiometric data for the Ozark Aquifer (Figure 4-5), the pump was well above the Ozark potentiometric surface therefore, only water from the SPA was pumped.
C01	164	103	17-Dec-14	105	108-154	0.49 gpm @ 103-108 ft	0.22 gpm @ 109-11 ft 0.2 gpm @ 116 ft 0.03 gpm @ 125 ft	N/A	2 gpm	not reported	not reported	117-154	0.06 gpm @ 116 ft 0.04 gpm @ 136 ft 0.73 gpm @ 149-152 ft	0.04 gpm @ 154-164 ft	N/A	pp. 115-116	Ambient flow at MW-C01 was characterized as “fairly significant downhole flow near surface, with a tapering of flow with depth." Due to rapid water level decline during the extraction test, test stations above 117 ft bgs were not able to be measured.
NE01	371	99	7-Oct-14 and 17-Dec-14	66 ft - 10/7 116 ft - 12/17	74-350	0.6 gpm @ 116-123 ft	0.26 gpm @ 125-127 ft 0.26 gpm @ 131-133 ft 0.05 gpm @ 143-146 ft	N/A	1.1 gpm	not reported	not reported	300-371	None	None	N/A	pp. 206-208	Prior to installing the permanent casing, ambient flow was measured at four depths between 74 and 97 ft bgs. Zero flow was recorded at every station. Flow measurement under pumping conditions was attempted; however, no flow could be induced from the formation. The deeper portion of the well was tested over the saturated interval, 116 to 350 ft bgs. Under pumping conditions at 1.1 gpm (extraction test), the water level fell rapidly as no flow could be induced from the formation. Because of the rapid fall of the water level, no measurements could be made above 300 ft. All measurements below 300 were either zero or less than 0.02 gpm.
NE02	230	166	6-Oct-14 and 18-Dec-14	89 ft - 10/6 91 ft - 12/18	145-227	0.49 gpm @ 141-142 ft 0.03 gpm @ 225.5 ft 0.06 gpm @ 227-230 ft	0.22 gpm @ 148 ft 0.20 gpm @ 153 ft 0.05 gpm @ 163 ft 0.06 gpm @165 ft	N/A	2.5 gpm	not reported	not reported	145-227	0.02 gpm @ 225.5 ft 0.06 gpm @ 227-230 ft	0.1 gpm @ 165 ft	N/A	pp. 262-263	Prior to installation of the permanent casing, in the extraction text an outflow of 0.13 gpm was measured immediately below the temporary casing. No other flow could be induced and the water level fell rapidly to the pump at a pumping rate of approximately 3.6 gpm. After installation of the permanent casing to 166 ft, only very small flows were measured under ambient conditions. Under a pumping rate of approximately 2.5 gpm, 0.1 gpm outflow was measured at 165 ft, 0.02 gpm inflow was measured at 225 ft, and 0.06 gpm inflow was measured from 227 to 230 ft bgs.
W02	80	N/A[3]	8-Oct-14	20	25-68	0.02 gpm @ 43 ft 0.11 gpm @ 44.5 ft 0.05 gpm @ 68-80 ft	0.17 gpm @ 39 ft	N/A	3.2 gpm	not reported	not reported	68-80 ft	0.06 gpm @ 68-80 ft	None	N/A	pp. 286-287	Permanent casing was not installed in this well as it was abandoned and replaced by MW-W02R.
W02R	240	80	30-Dec-14	10	106-225	0.21 gpm @ 10-106 ft	0.15 gpm @ 108 ft 0.03 gpm @ 113 ft 0.02 gpm @ 124 ft	N/A	1 gpm	not reported	not reported	212-240 ft	0.2 gpm @ 223 ft	None	N/A	pp. 346-347	MW-W02R was tested after installation of permanent casing.

Notes:

1. bgs = below ground surface
2. SPA = Springfield Plateau Aquifer
3. Permanent casing not installed in this well as it was abandoned and replaced by MW-W02R.
4. The flowmeter range is 0.02 gpm to 10 gpm. Therefore, 0.01 gpm measurements are not considered reliable and have been omitted from this summary table.
5. All flowmeter results and data provided by IDS.

Table 3-5:
Summary of Packer Test Results
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, Missouri

Well	Well Depth, ft	Casing Depth, ft bgs	Test Date	Approx. Test Duration, Hours	Type of Packer Assembly	For Single Packer: Packer Depth (ft bgs) and Formation	For Straddle Packer: Isolation Interval (ft bgs) and Formation	Depth to Water Level at Start of Test, ft bgs	Calculated Depth to SPA Water Level at End of Test, ft bgs	Calculated Depth to Ozark Water Level at End of Test, ft bgs	Calculated Depth to Pierson Water Level at End of Test, ft bgs	Ground Elev, ft	Water Elev Ozark, ft amsl	Water Elev SPA, ft amsl	Head Difference Between the SPA and Ozark, ft	Relevant Section/ Figure in IDS Report (Appendix L)	Notes on Test
119	535	83	19-Oct-14	1.5	Single	307/Chattanooga Shale	NA	75	72	165	NA	1142	977	1070	93	WELL 119:1	Both transducers stabilized fairly quickly, and water levels in both aquifers were calculated based on the final transducer readings. The depth to water in the OBI, done on October 21, 2015, was 79 ft bgs.
1360-2	676	83	22-Oct-14	6.6	Single	410/Chattanooga Shale	NA	277	139	292	NA	1219	927	1080	153	1360-2:1	The Ozark transducer stabilized quickly. The SPA transducer did not stabilize. Depths to water shown are based on the final transducer readings. While a representative polynomial curve reportedly did not fit the SPA data, visually, it appears that the final transducer pressure, if stabilized, may have been 6 or 8 psi greater (additional 14 to 18 ft = depth of 121 to 125 ft bgs for the SPA, or elev 1094 to 1098 ft amsl; with the resulting head difference between the SPA and the Ozark of 167 to 171 ft). The depth to the water level in the OBI (December 17, 2012) was 273 ft bgs.
1360-2	676	83	17-Dec-14	4.7	Straddle	NA	380 to 384/ Pierson	281	120	295	204; see notes at right	1219	924	1099	175	1362-2:2	The Ozark transducer stabilized quickly and the depth to water in the Ozark is based on the final transducer reading, as is the Pierson depth to water. The Pierson data is questionable as the transducer pressure experienced a small initial very sharp rise then gradually fell back to approximately the initial pressure. This may indicate that the Pierson is relatively impermeable and not well-connected to the SPA. The SPA was still rising at the end of the test, and the calculated depth to water is based on a best polynomial fit at 8.3 hours.
A035143	427	119	20-Oct-14	6.5	Single	374/Chattanooga Shale	NA	129	102	222	NA	1217	995	1115	120	A035143:1	The Ozark transducer stabilized quickly. The SPA transducer did not stabilize. Depths to water shown are based on the final transducer readings. Visually, it appears that the final transducer pressure, if stabilized, may have been approximately 5 psi greater (additional 12 ft = depth of 90 ft bgs for the SPA, or elev 1127 ft amsl; with the resulting head difference between the SPA and the Ozark of 132 ft).
A035143	427	119	18-Dec-14	4.5	Straddle	NA	349 to 353/ Pierson	121	100	213	50; see notes at right	1217	1004	1117	113	A035143:2	All calculated depths to water level are based on the final transducer readings. The Ozark transducer stabilized quickly. The SPA transducer pressure was still rising; visually, it appears that it would rise another 3 psi (= additional 7 ft = depth 93 ft bgs for the SPA, or elev 1124 amsl; with the resulting head difference between the SPA and the Ozark of 120 ft). The Pierson data is unlikely reflective of the actual water level and likely indicates that the Pierson is relatively impermeable and the pressure was unable to dissipate.
A071672	449	82	14-Oct-14	Ozark, 7.7 SPA, 17	Single	321/Chattanooga Shale	NA	212	198	204	NA	1187	983	989	6	A071672:1	Calculated depths to water are based on the final transducer readings. The Ozark transducer stabilized quickly. The SPA transducer pressure was steadily rising throughout the test. Note that pre-test depth to water is greater than either calculated depth; a highly unlikely scenario. Based on the potentiometric surface maps (Figures 4-4 and 4-5), the head difference between the SPA and the Ozark at this location is around 80 ft.
NE01	371	99	16-Dec-14	3.7	Straddle	NA	353 to 357/ Pierson	113	113	NA	NA; see notes at right.	1226	NA	1113	NA	MW-NE01:5	Calculated depths to water are based on the final transducer readings. As this is not a crossover well, the water level in the SPA did not change. The pressure in the lower zone (below 360 ft bgs) exceeded the limits of the transducer for the duration of the test, indicating a relatively impermeable zone below the packer. Similarly, the pressure did not dissipate in the middle interval, likely due to the relative impermeability of this zone.

Notes:

bgs = below ground surface

SPA = Springfield Plateau Aquifer

psi = Pounds per square inch

Table 3-6:
Stream and Spring Measurements
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, MO

Site	Name and Location	Elevation (ft AMSL)	Date	Conductivity (mS/cm)	Temperature (°C)	pH	Dissolved Oxygen (%)	Turbidity (NTU)	Discharge (ft^3/sec)
Stream 1	Elm Spring Branch - above HH Bridge	1101.3	2/27/2013	0.27	4.7	6.83	7.78	0.0	0.66
Stream 1	Elm Spring Branch - above HH Bridge	1101.3	5/22/2013	0.15	14.1	7.59	8.96	not measured	2.57
Stream 1	Elm Spring Branch - above HH Bridge	1101.3	8/14/2013	0.17	16.5	7.37	9.15	0.0	4.76
Stream 1	Elm Spring Branch - above HH Bridge	1101.3	11/13/2013	Dry					
Stream 1	Elm Spring Branch - above HH Bridge	1101.3	1/19/2015	Dry					
Stream 2	Elm Spring Branch - Above Norway Rd	1067.9	2/27/2013	Dry					
Stream 2	Elm Spring Branch - Above Norway Rd	1067.9	5/22/2013	0.14	14.1	6.6	5.44	not measured	0.07
Stream 2	Elm Spring Branch - Above Norway Rd	1067.9	8/14/2013	not measured					0.12
Stream 2	Elm Spring Branch - Above Norway Rd	1067.9	11/13/2013	Dry					
Stream 2	Elm Spring Branch - Above Norway Rd	1067.9	1/19/2015	Dry					
Stream 3	Elm Spring Branch - Xing to Unicorn Spring	1065.8	2/27/2013	Dry					
Stream 3	Elm Spring Branch - Xing to Unicorn Spring	1065.8	5/22/2013	0.14	14.7	6.83	7.44	not measured	1.03
Stream 3	Elm Spring Branch - Xing to Unicorn Spring	1065.8	8/14/2013	0.19	17.7	6.73	5.02	0.3	1.39
Stream 3	Elm Spring Branch - Xing to Unicorn Spring	1065.8	11/13/2013	Dry					
Stream 3	Elm Spring Branch - Xing to Unicorn Spring	1065.8	1/19/2015	Dry					
Stream 4	Hickory Creek - RR Bridge	1056.0	2/27/2013	0.30	10.4	7	11.11	0.0	7.77
Stream 4	Hickory Creek - RR Bridge	1056.0	5/22/2013	0.19	15.9	7.32	9.67	not measured	6.96
Stream 4	Hickory Creek - RR Bridge	1056.0	8/15/2013	0.27	15.3	7.16	8.32	0.7	5.37
Stream 4	Hickory Creek - RR Bridge	1056.0	11/12/2013	0.32	10.6	7.45	7.59	0.9	0.90
Stream 4	Hickory Creek - RR Bridge	1056.0	1/22/2015	0.26	7.0	7.89	13.63	0.8	See Note 4.

Table 3-6:
Stream and Spring Measurements
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, MO

Site	Name and Location	Elevation (ft AMSL)	Date	Conductivity (mS/cm)	Temperature (°C)	pH	Dissolved Oxygen (%)	Turbidity (NTU)	Discharge (ft^3/sec)
Stream 5	Hickory Creek - Alt 71 Bridge	1039.3	2/26/2013	0.27	9.3	7.47	9.56	5	16.68
Stream 5	Hickory Creek - Alt 71 Bridge	1039.3	5/20/2013	0.18	15.6	7.44	9.88	not measured	47.50
Stream 5	Hickory Creek - Alt 71 Bridge	1039.3	8/14/2013	0.23	17.4	7.12	7.94	17.1	32.68
Stream 5	Hickory Creek - Alt 71 Bridge	1039.3	11/12/2013	0.31	11.1	7.44	8.77	11	7.05
Stream 5	Hickory Creek - Alt 71 Bridge	1039.3	1/19/2015	0.25	10.1	8.23	12.6	1.64	See Note 4.
Stream 6	Hickory Creek - Humphrey	1026.9	2/26/2013	0.28	8.0	7.09	10.1	0.2	23.56
Stream 6	Hickory Creek - Humphrey	1026.9	5/21/2013	0.18	14.5	7.37	9.75	not measured	42.53
Stream 6	Hickory Creek - Humphrey	1026.9	8/13/2013	0.24	17.0	7.27	9.07	1	28.29
Stream 6	Hickory Creek - Humphrey	1026.9	11/12/2013	0.31	11.2	7.49	10.53	4	6.21
Stream 6	Hickory Creek - Humphrey	1026.9	1/19/2015	0.27	9.0	8.23	13.22	0.42	See Note 4.
Stream 7	Hickory Creek - Park on McKinney St.	1012.2	2/26/2013	0.29	7.7	6.67	10.24	not measured	24.82
Stream 7	Hickory Creek - Park on McKinney St.	1012.2	5/21/2013	0.19	14.5	6.94	9.78	not measured	47.65
Stream 7	Hickory Creek - Park on McKinney St.	1012.2	8/13/2013	0.23	17.1	7.5	9.9	0.0	48.02
Stream 7	Hickory Creek - Park on McKinney St.	1012.2	11/11/2013	0.29	14.3	7.77	9.88	0.0	12.48
Stream 7	Hickory Creek - Park on McKinney St.	1012.2	1/19/2015	0.29	9.0	8.33	13.84	0.98	See Note 4.
Stream 8	Buffalo Creek - Low-Water Xing on Jay Dr.	1083.2	2/25/2013	0.47	7.2	7.5	11.09	not measured	1.14
Stream 8	Buffalo Creek - Low-Water Xing on Jay Dr.	1083.2	5/22/2013	0.26	16.7	7.48	6.04	not measured	1.47
Stream 8	Buffalo Creek - Low-Water Xing on Jay Dr.	1083.2	8/14/2013	0.28	18.0	6.52	7.27	0.0	6.06
Stream 8	Buffalo Creek - Low-Water Xing on Jay Dr.	1083.2	11/13/2013	0.38	11.1	7.59	2.7	29	0.06
Stream 8	Buffalo Creek - Low-Water Xing on Jay Dr.	1083.2	1/21/2015	0.41	7.5	7.89	10.44	0.79	See Note 4.

Table 3-6:
Stream and Spring Measurements
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, MO

Site	Name and Location	Elevation (ft AMSL)	Date	Conductivity (mS/cm)	Temperature (°C)	pH	Dissolved Oxygen (%)	Turbidity (NTU)	Discharge (ft^3/sec)
Stream 9	Nowak Stream	1070.1	2/25/2013	0.44	8.0	7.68	19.47	not measured	4.08
Stream 9	Nowak Stream	1070.1	5/23/2013	0.26	16.2	7.76	10.5	not measured	3.14
Stream 9	Nowak Stream	1070.1	8/14/2013	0.27	18.9	7.2	10.02	0.6	11.72
Stream 9	Nowak Stream	1070.1	11/13/2013	0.36	12.0	7.73	8.74	16.9	0.15
Stream 9	Nowak Stream	1070.1	1/21/2015	0.32	8.2	8.19	13.83	1.27	See Note 4.
Stream 10	Crowder Stream	1190.7	2/27/2013	0.28	6.0	6.48	10.46	0.3	0.22
Stream 10	Crowder Stream	1190.7	5/20/2013	0.21	16.1	7.4	9.52	not measured	0.43
Stream 10	Crowder Stream	1190.7	8/14/2013	0.26	16.0	7.25	8.35	0.0	0.78
Stream 10	Crowder Stream	1190.7	11/13/2013	0.32	7.5	7.47	9.15	0.0	0.13
Stream 10	Crowder Stream	1190.7	1/21/2015	0.36	4.3	7.86	13.59	0.61	See Note 4.
Stream 11	Hickory Creek - City Park Picnic Tables	1003.0	2/26/2013	0.30	7.2	7.25	8.81	0.0	14.12
Stream 11	Hickory Creek - City Park Picnic Tables	1003.0	5/21/2013	0.19	14.6	7.53	9.46	not measured	45.42
Stream 11	Hickory Creek - City Park Picnic Tables	1003.0	8/13/2013	0.25	17.3	7.51	9.67	0.0	39.52
Stream 11	Hickory Creek - City Park Picnic Tables	1003.0	11/11/2013	0.32	14.2	7.64	15.2	0.0	10.03
Stream 11	Hickory Creek - City Park Picnic Tables	1003.0	1/19/2015	0.29	9.0	8.33	14.06	1.13	See Note 4.
Stream 12	Bullskin Creek	1158.8	2/27/2013	0.28	11.5	6.56	9.64	0.0	1.02
Stream 12	Bullskin Creek	1158.8	5/20/2013	0.19	14.4	7.18	9.9	not measured	1.02
Stream 12	Bullskin Creek	1158.8	8/12/2013	0.17	16.5	6.52	8.99	0.7	2.65
Stream 12	Bullskin Creek	1158.8	11/13/2013	0.34	12.5	7.64	9.97	5.1	0.25
Stream 12	Bullskin Creek	1158.8	1/21/2015	0.33	9.4	8.13	12.77	1.38	See Note 4.

Table 3-6:
Stream and Spring Measurements
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, MO

Site	Name and Location	Elevation (ft AMSL)	Date	Conductivity (mS/cm)	Temperature (°C)	pH	Dissolved Oxygen (%)	Turbidity (NTU)	Discharge (ft^3/sec)
Stream 13	Elm Spring Branch - Below Unicorn Spring	1056.8	Added to sampling list at 2nd quarter 2013						
Stream 13	Elm Spring Branch - Below Unicorn Spring	1056.8	5/22/2013	0.10	14.5	6.94	9.1	not measured	12.96
Stream 13	Elm Spring Branch - Below Unicorn Spring	1056.8	8/15/2013	0.22	15.2	6.68	8.67	1.1	11.23
Stream 13	Elm Spring Branch - Below Unicorn Spring	1056.8	11/12/2013	0.30	14.5	7.5	10.52	16.6	4.34
Stream 13	Elm Spring Branch - Below Unicorn Spring	1056.8	1/22/2015	0.28	12.1	7.73	17.96	0.62	See Note 4.
Stream 14	Un-named Stream - Soccer Fields	1038.8	Added to sampling list at 2nd quarter 2013						
Stream 14	Un-named Stream - Soccer Fields	1038.8	5/21/2013	0.26	15.7	7.92	8.89	not measured	0.53
Stream 14	Un-named Stream - Soccer Fields	1038.8	8/13/2013	0.31	16.8	7.72	8.16	3.6	0.66
Stream 14	Un-named Stream - Soccer Fields	1038.8	11/11/2013	0.32	13.9	7.95	9.22	0.0	0.08
Stream 14	Un-named Stream - Soccer Fields	1038.8	1/19/2015	0.22	7.6	8.32	12.74	4.5	See Note 4.
Spring 1	Elm Spring	1155.3	2/28/2013	0.29	13.3	5.98	7.75	0.2	11.05
Spring 1	Elm Spring	1155.3	5/21/2013	not measured	13.2	6.2	8.65	not measured	7.43
Spring 1	Elm Spring	1155.3	8/13/2013	0.18	15.0	5.69	6.86	not measured	7.02
Spring 1	Elm Spring	1155.3	11/12/2013	0.32	14.3	6.4	9.1	7.5	1.66
Spring 1	Elm Spring	1155.3	1/20/2015	0.32	12.3	7.35	10.57	0.45	See Note 4.
Spring 2	Quarry Spring	1064.7	2/27/2013	0.33	12.5	6.49	9.11	4.4	0.38
Spring 2	Quarry Spring	1064.7	5/20/2013	0.22	13.6	7.07	8.71	not measured	0.40
Spring 2	Quarry Spring	1064.7	8/12/2013	0.26	15.2	6.48	7.71	0.0	0.42
Spring 2	Quarry Spring	1064.7	11/13/2013	0.30	15.3	7.2	9.52	7	0.09
Spring 2	Quarry Spring	1064.7	1/21/2015	0.33	13.2	7.67	10.86	0.38	See Note 4.

Table 3-6:
Stream and Spring Measurements
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, MO

Site	Name and Location	Elevation (ft AMSL)	Date	Conductivity (mS/cm)	Temperature (°C)	pH	Dissolved Oxygen (%)	Turbidity (NTU)	Discharge (ft^3/sec)
Spring 3	Unicorn Spring	1060.8	2/27/2013	0.31	11.7	6.74	7.7	0.0	7.27
Spring 3	Unicorn Spring	1060.8	5/22/2013	0.17	13.9	6.85	8.43	not measured	9.74
Spring 3	Unicorn Spring	1060.8	8/14/2013	0.23	15.1	6.46	8.85	3.9	10.81
Spring 3	Unicorn Spring	1060.8	11/13/2013	0.31	14.3	7.21	7.68	8.6	1.87
Spring 3	Unicorn Spring	1060.8	10/9/2014	0.32	14.3	7.25	See Note 4.	3.21	See Note 4.
Spring 3	Unicorn Spring	1060.8	10/16/2014	0.26	14.8	7.05	See Note 4.	2.31	See Note 4.
Spring 3	Unicorn Spring	1060.8	10/24/2014	0.28	14.7	7.11	See Note 4.	2.3	See Note 4.
Spring 3	Unicorn Spring	1060.8	12/6/2014	0.33	12.9	6.9	See Note 4.	1.99	See Note 4.
Spring 3	Unicorn Spring	1060.8	12/18/2014	0.28	14.1	7.07	See Note 4.	13.45	See Note 4.
Spring 3	Unicorn Spring	1060.8	1/22/2015	0.28	13.3	7.35	11.8	0.3	3.20
Spring 3	Unicorn Spring	1060.8	2/2/2015	0.28	12.7	6.95	9.48	3.02	1.73
Spring 4	McMahan Spring	1062.5	2/28/2013	0.32	11.7	6.22	6.65	0.0	17.69
Spring 4	McMahan Spring	1062.5	5/21/2013	0.18	13.8	6.42	7.96	not measured	16.22
Spring 4	McMahan Spring	1062.5	8/13/2013	0.26	15.2	6.37	7.7	0.0	13.87
Spring 4	McMahan Spring	1062.5	11/12/2013	0.33	14.9	6.8	7.6	4.5	2.92
Spring 4	McMahan Spring	1062.5	1/20/2015	0.32	12.2	7.39	10.58	0.44	See Note 4.

Table 3-6:
Stream and Spring Measurements
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, MO

Site	Name and Location	Elevation (ft AMSL)	Date	Conductivity (mS/cm)	Temperature (°C)	pH	Dissolved Oxygen (%)	Turbidity (NTU)	Discharge (ft^3/sec)
Spring 5	Alt. 71 Hwy Spring	1061.1	2/28/2013	0.33	13.6	5.99	6.47	4.8	1.29
Spring 5	Alt. 71 Hwy Spring	1061.1	5/20/2013	0.21	13.8	6.78	8.36	not measured	0.68
Spring 5	Alt. 71 Hwy Spring	1061.1	8/13/2013	0.27	13.7	6.22	8.12	0.0	0.51
Spring 5	Alt. 71 Hwy Spring	1061.1	11/12/2013	0.33	13.8	6.94	6.9	9.6	0.05
Spring 5	Alt. 71 Hwy Spring	1061.1	10/9/2014	0.20	14.9	6.05	See Note 4.	1.03	See Note 4.
Spring 5	Alt. 71 Hwy Spring	1061.1	10/16/2014	0.29	15.2	6.09	See Note 4.	1.08	See Note 4.
Spring 5	Alt. 71 Hwy Spring	1061.1	10/24/2014	0.32	15.1	7.13	See Note 4.	1.22	See Note 4.
Spring 5	Alt. 71 Hwy Spring	1061.1	12/6/2014	0.36	13.4	7.17	See Note 4.	0.78	See Note 4.
Spring 5	Alt. 71 Hwy Spring	1061.1	12/18/2014	0.33	13.5	7.14	See Note 4.	1.76	See Note 4.
Spring 5	Alt. 71 Hwy Spring	1061.1	1/20/2015	0.33	12.5	7.3	9.79	0.63	0.16
Spring 5	Alt. 71 Hwy Spring	1061.1	2/2/2015	0.29	12.8	6.77	6.88	1.64	0.02

Spring 6	Carter Spring	1059.6	2/28/2013	0.45	13.5	6.5	7.69	2.4	0.10
Spring 6	Carter Spring	1059.6	5/21/2013	0.25	14.3	6.88	8.57	not measured	0.31
Spring 6	Carter Spring	1059.6	8/13/2013	0.09	14.5	7.71	8.91	not measured	0.13
Spring 6	Carter Spring	1059.6	11/11/2013	0.33	15.2	7.82	7.4	13.9	0.05
Spring 6	Carter Spring	1059.6	10/9/2014	1.48	15.6	6.43	See Note 4.	1.11	See Note 4.
Spring 6	Carter Spring	1059.6	10/16/2014	0.32	15.1	6.9	See Note 4.	2.38	See Note 4.
Spring 6	Carter Spring	1059.6	10/24/2014	0.36	15.2	6.73	See Note 4.	1.25	See Note 4.
Spring 6	Carter Spring	1059.6	12/6/2014	0.40	14.5	7.17	See Note 4.	1.63	See Note 4.
Spring 6	Carter Spring	1059.6	12/18/2014	0.36	14.4	6.47	See Note 4.	1.1	See Note 4.
Spring 6	Carter Spring	1059.6	1/20/2015	0.39	12.3	7.47	10.48	1.28	1.27
Spring 6	Carter Spring	1059.6	2/2/2015	0.17	12.9	6.94	8.66	1.9	0.01

Table 3-6:
Stream and Spring Measurements
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, MO

Site	Name and Location	Elevation (ft AMSL)	Date	Conductivity (mS/cm)	Temperature (°C)	pH	Dissolved Oxygen (%)	Turbidity (NTU)	Discharge (ft^3/sec)
Spring 7	Dog Spring	1130.6	2/28/2013	0.33	5.9	6.43	7.93	0.0	Insufficient to measure
Spring 7	Dog Spring	1130.6	5/23/2013	0.19	13.9	7.79	10.59	not measured	0.04
Spring 7	Dog Spring	1130.6	8/15/2013	0.21	14.8	7.69	9.59	5	Insufficient to measure
Spring 7	Dog Spring	1130.6	11/13/2013	Insufficient Flow					
Spring 7	Dog Spring	1130.6	1/22/2015	0.37	10.8	8.3	12.57	0.83	See Note 4.
Spring 8	Hearrell Spring	1044.3	2/28/2013	0.44	14.1	6.29	8.38	0.0	1.12
Spring 8	Hearrell Spring	1044.3	5/21/2013	0.26	14.8	6.91	9.15	not measured	4.22
Spring 8	Hearrell Spring	1044.3	8/13/2013	0.32	15.8	6.31	8.03	0.0	5.62
Spring 8	Hearrell Spring	1044.3	11/12/2013	0.37	15.4	6.39	8.64	8.7	2.61
Spring 8	Hearrell Spring	1044.3	1/20/2015	0.39	12.3	7.3	10.47	0.51	See Note 4.
Spring 9	Big Spring	1023.5	2/26/2013	0.42	14.3	7.1	9.88	7.6	7.74
Spring 9	Big Spring	1023.5	5/22/2013	0.27	14.7	6.92	9.88	not measured	5.05
Spring 9	Big Spring	1023.5	8/13/2013	0.40	16.8	6.55	7.32	0.0	8.77
Spring 9	Big Spring	1023.5	11/11/2013	0.52	17.5	7.67	6.15	0.0	4.65
Spring 9	Big Spring	1023.5	1/19/2015	0.36	14.1	8.34	10.4	0.46	See Note 4.
Spring 10	Nowak Spring	1090.5	2/28/2013	Insufficient Flow					
Spring 10	Nowak Spring	1090.5	5/23/2013	Insufficient Flow					
Spring 10	Nowak Spring	1090.5	8/14/2013	Insufficient Flow					
Spring 10	Nowak Spring	1090.5	11/13/2013	Dry					
Spring 10	Nowak Spring	1090.5	1/21/2015	Dry					

Table 3-6:
Stream and Spring Measurements
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, MO

Site	Name and Location	Elevation (ft AMSL)	Date	Conductivity (mS/cm)	Temperature (°C)	pH	Dissolved Oxygen (%)	Turbidity (NTU)	Discharge (ft^3/sec)
Spring 11	Monark Spring	1143.7	Did not visit						
Spring 11	Monark Spring	1143.7	5/22/2013	0.17	13.0	6.72	9.86	not measured	0.17
Spring 11	Monark Spring	1143.7	8/14/2013	0.28	15.3	7.44	9.5	2.1	not measured
Spring 11	Monark Spring	1143.7	11/11/2013	Dry					
Spring 11	Monark Spring	1143.7	1/19/2015	0.31	8.5	7.4	10.8	0.67	See Note 4.
Spring 12	Crowder Spring	1063.7	2/27/2013	0.34	11.8	6.0	8.48	0.0	0.64
Spring 12	Crowder Spring	1063.7	5/20/2013	0.18	12.5	6.45	9.47	not measured	0.66
Spring 12	Crowder Spring	1063.7	8/14/2013	0.25	15.6	6.81	7.44	0.0	1.99
Spring 12	Crowder Spring	1063.7	11/13/2013	0.31	15.0	7.05	7.44	11.4	0.24
Spring 12	Crowder Spring	1063.7	1/21/2015	0.30	12.2	7.46	11.38	0.7	See Note 4.
Spring 15	Bartholic Spring	1159.2	Did not visit						
Spring 15	Bartholic Spring	1159.2	5/21/2013	0.14	13.0	6.11	8.49	not measured	3.60
Spring 15	Bartholic Spring	1159.2	8/13/2013	0.17	13.8	5.61	7.69	0.0	18.32
Spring 15	Bartholic Spring	1159.2	11/12/2013	0.33	13.9	6.76	8.02	19.7	1.35
Spring 15	Bartholic Spring	1159.2	1/20/2015	0.33	12.4	7.25	10.29	1	See Note 4.
Spring 16	Unnamed Spring Along Buffalo Creek	1158.4	1/20/2015	Dry					
Spring 17	Unnamed Spring, Elm Spr. Branch E of CTA	1158.1	1/20/2015	0.29	13.2	7.12	10.65	1.01	See Note 4.

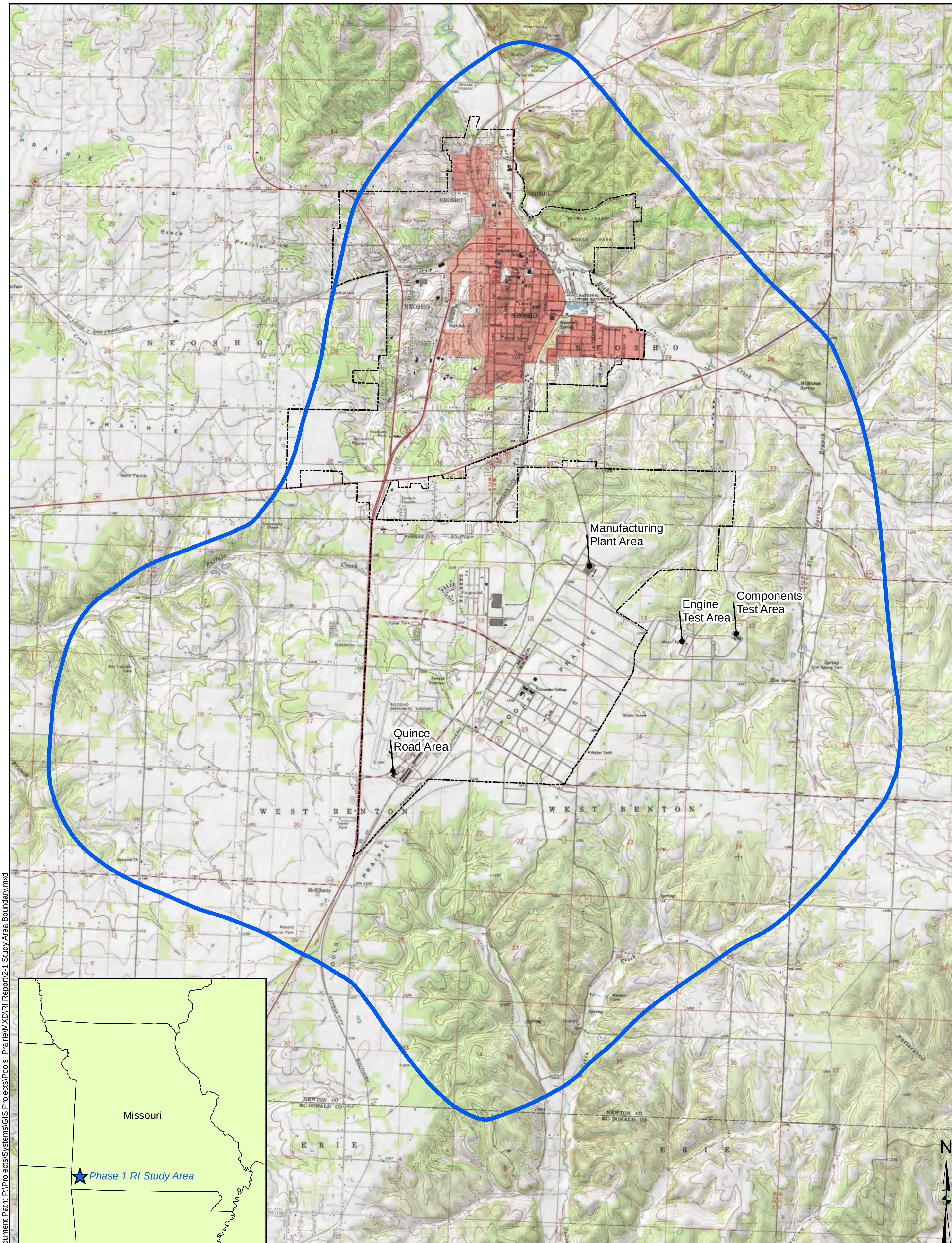
Table 3-6:
Stream and Spring Measurements
Phase 1 Remedial Investigation
Pools Prairie Superfund Site, Newton County, MO

Site	Name and Location	Elevation (ft AMSL)	Date	Conductivity (mS/cm)	Temperature (°C)	pH	Dissolved Oxygen (%)	Turbidity (NTU)	Discharge (ft^3/sec)
Spring 18	Unnamed Spring, Adjacent to Carter Spring	1151.7	1/20/2015	Dry					
Spring 19	Unnamed Spring, MO HH W of Elm Spr Branch	1117.1	1/20/2015	0.44	5.2	7.62	10.32	9.47	See Note 4.
Spring 20	Big Spring - Park Grotto	1027.2	1/19/2015	0.36	14.2	8.03	10.66	0.48	See Note 4.
Spring 21	Kodiak Rd Bridge	1121.9	1/21/2015	0.41	10.5	7.97	12.8	1.28	See Note 4.
Spring 22	Unnamed Spring Along Buffalo Creek	1078.8	1/21/2015	0.41	5.2	7.83	8.12	18.1	See Note 4.
Spring 23	Unnamed Spring, Jay Dr. and Palm Rd.	1149.5	1/21/2015	0.44	6.7	7.67	9.26	40.2	See Note 4.
Spring 24	Ben Lassiter	NM	1/21/2015	No Access/Dry					
Spring 25	Unnamed Spring, Harrison Branch at Jaguar Rd.	1155.6	1/21/2015	0.33	9.4	7.41	9.29	1.7	See Note 4.

Notes:

1. AMSL - above mean sea level
2. mS/cm - millisiemen per centimeter
3. NTU - Nephelometric Turbidity Unit
4. Sufficient discharge data was collected for most springs in 2013. Work completed in 2014-2015 included planned flow measurements for only Springs 3, 5 and 6.

Figures



Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\2-1 Study Area Boundary.mxd

Phase 1 RI Study Area
Neosho City Limits

0 2,250 4,500 9,000
Feet

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

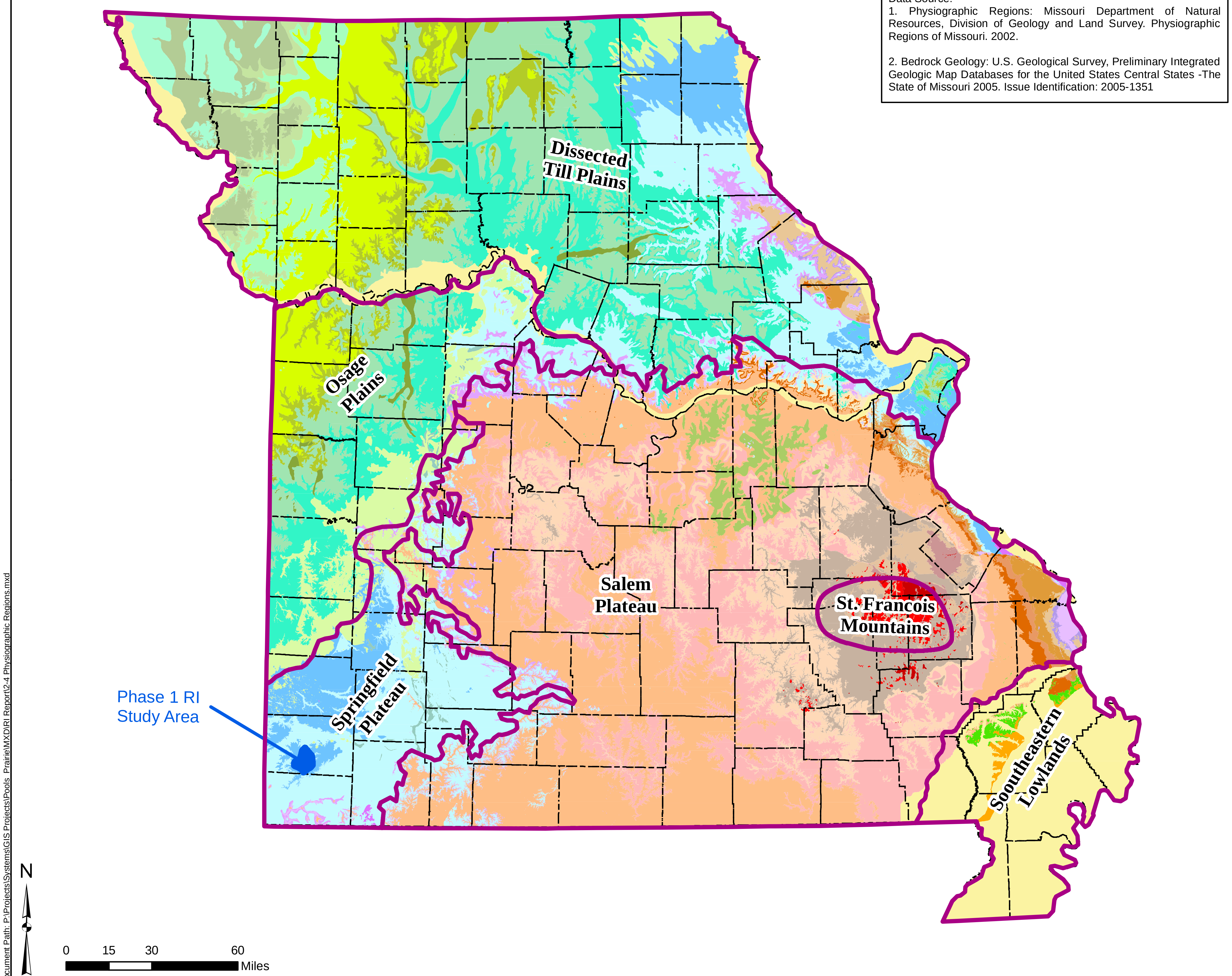
Study Area Boundary

DRN. BY: IJP
CHKD. BY: HB
12/1/2015

AECOM

FIG. NO.
1-1

Data Source:
1. RI Phase 1 Investigation Boundary and Source Areas delineated in Administrative Settlement Agreement and Order on Consent, Docket No. CERCLA-07-2011-0014, Figure 1.



Data Source:
1. Physiographic Regions: Missouri Department of Natural Resources, Division of Geology and Land Survey. Physiographic Regions of Missouri. 2002.

2. Bedrock Geology: U.S. Geological Survey, Preliminary Integrated Geologic Map Databases for the United States Central States -The State of Missouri 2005. Issue Identification: 2005-1351

Physiographic Region Boundaries
Phase 1 RI Study Area
Missouri Counties

Uppermost Bedrock Geologic Unit

- Quaternary alluvium
- Tertiary undifferentiated
- Cretaceous System undifferentiated
- Pennsylvanian System undifferentiated
- Pennsylvanian, Douglass Group
- Pennsylvanian, Wabaunsee
- Pennsylvanian, Shawnee
- Pennsylvanian, Lansing & Pedee
- Pennsylvanian, Kansas City
- Pennsylvanian, Pleastanton, Warrensburg
- Pennsylvanian, Pleasanton
- Pennsylvanian, Marmaton
- Pennsylvanian, Cherokee, Cabaniss
- Pennsylvanian channel sandstones
- Pennsylvanian, Cherokee, Krebs
- Mississippian, Chesterian Series
- Mississippian, Meramecian Series
- Mississippian, Osagean Series
- Mississippian, Kinderhookian Series
- Devonian System undifferentiated
- Silurian System undifferentiated
- Ordovician, maquoketa Group & Kimmswick Ls
- Ordovician, Decorah & Plattin
- Ordovician, Joachim Dolomite
- Ordovician, Joachim & Dutchtown
- Ordovician, St. Peter
- Ordovician, St. Peter & Everton
- Ordovician, Cotter
- Ordovician, Cotter & Jefferson City
- Ordovician, Roubidoux
- Ordovician, Gasconade
- Ordovician System undifferentiated
- Cambrian, Eminence & Potosi
- Cambrian, Elvins & Bonneterre
- Cambrian, Lamotte
- Precambrian Volcanics
- Precambrian Intrusives
- Precambrian Mafics

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Physiographic Regions of Missouri

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 2-1

ESTIMATED STRATIGRAPHIC COLUMN – POOLS PRAIRIE

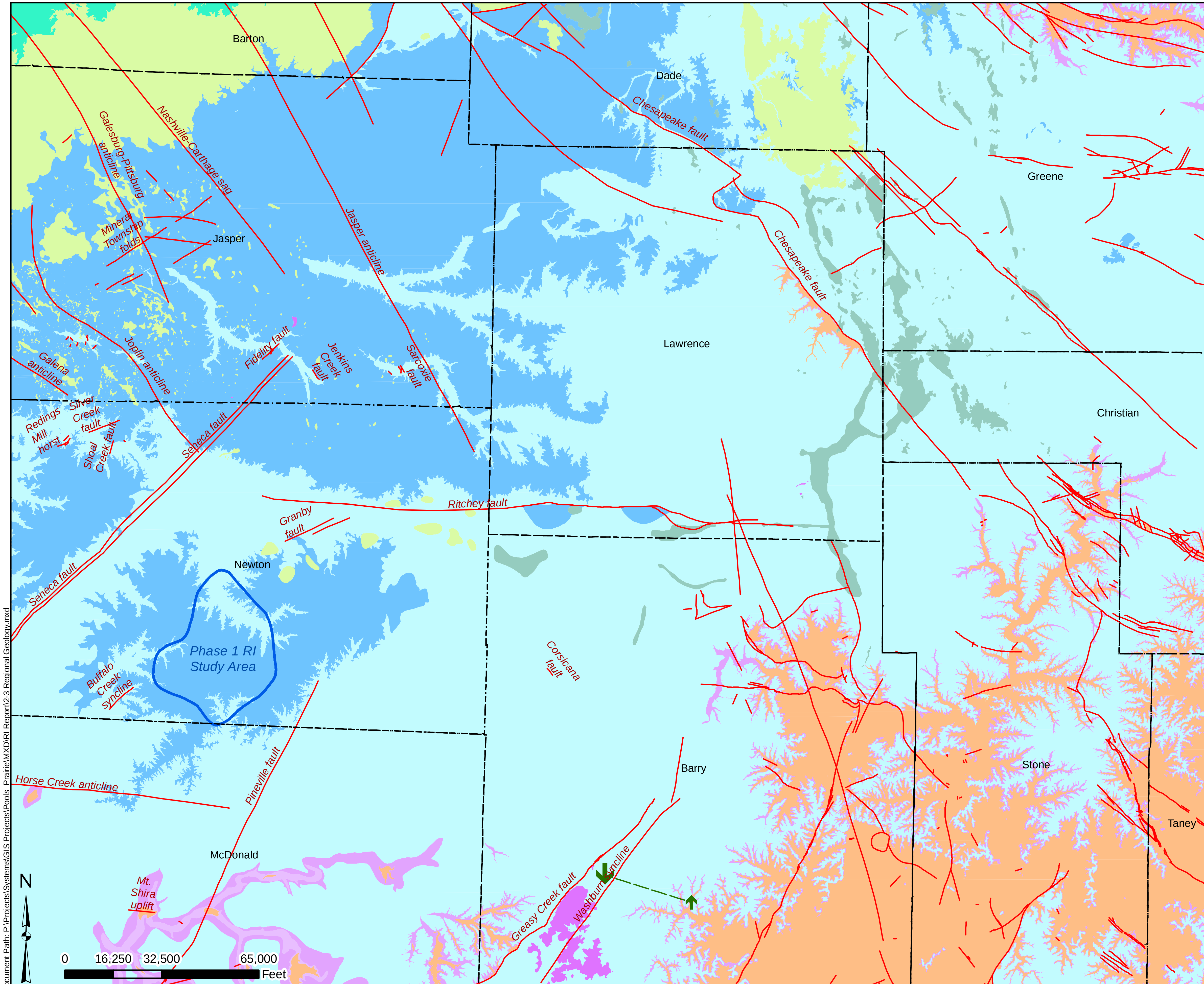
SYSTEM	HYDROGEOLOGIC UNIT	STRATIGRAPHIC UNIT	APPROX. THICKNESS
Mississippian	Springfield Plateau Aquifer	**Warsaw Formation** – Upper calcarenite over crystalline cherty limestone.	<100 ft.
		Burlington-Keokuk Formations – Medium to coarsely crystalline cherty limestone. Very similar in appearance to the Warsaw. Where present, the uppermost oolitic Short Creek Member is used as a marker between the two formations.	220 ft.
		Elsey Formation – Fine-grained limestone w/ abundant white to gray-white chert.	30 ft.
		Reeds Springs-Formation – Finely crystalline limestone with abundant dark gray sandy chert.	125 ft.
		Pierson Formation – Dolomitic limestone, cream-colored. May be part of the Ozark Confining Unit.	16.0-23.5 ft
	Ozark Confining Unit	**Northview Formation** – Variable lithology ranging between brown siltstone to green silty shale, not logged in all wells.	1.8-3.5 ft.
		Compton Formation – Very finely crystalline limestone, locally dolomitic, no chert.	6.8-10 ft.
		UNCONFORMITY	
Devonian		**Sylamore Sandstone** - Sandstone associated with late Devonian Chattanooga Shale.	0.3-0.6 ft.
		Chattanooga Shale - Fissile, black, carbonaceous, sandy shale. Thickens considerably to the south in McDonald County and into Arkansas.	6.9-15.8 ft.
		UNCONFORMITY	
Ordovician	Ozark Aquifer	**Cotter Formation –** Dolomite and cherty dolomite w/ minor sandstone beds and thin green shale partings.	Avg. 200 ft.
		Jefferson City Formation – Dolomite and cherty dolomite, contains oolitic chert.	Avg. 200 ft.
		Roubidoux Formation – Dolomite with cherty dolomite w/ scattered beds of dolomitic sandstone.	200 ft.
		Gasconade Formation – **Upper Gasconade member** – Finely- to medium-crystalline dolomite, low chert content.	40 – 70 ft.
		Lower Gasconade member – Dolomite w/ high chert content in the upper ≈150 feet of the member.	250 ft.
		Gunter Sandstone member – Over much of the area, the member consists of sandy dolomite w/ sand content ranging from 20 to 100 percent.	30 ft.
Cambrian		**Eminence Formation** – Dolomite, finely- to medium-crystalline w/ less than 5 percent chert.	200 ft.
		Potosi Formation – Dolomite, finely- to medium-crystalline, massive to thick-bedded.	<50 ft.

Data Sources:

1. Miller, Don E. and James Vandike, 1997. Groundwater Resources of Missouri. Missouri State Water Plan Series Volume II. Missouri Department of Natural Resources.

2. Modifications and details added by AECOM were based on review of boring and well logs from multiple sources and on optical borehole imaging.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811	
Estimated Stratigraphic Column		
DRN. BY: JM CHKD. BY: MCH 7/16/15	AECOM	FIG. NO. 2-2



County Boundaries
Phase 1 RI Study Area
Geologic Structures

Uppermost Bedrock Geologic Unit

- Pennsylvanian, Cherokee, Krebs
- Pennsylvanian, Cherokee, Cabaniss
- Pennsylvanian channel sandstones
- Warsaw Formation: Mississippian, Meramecian Series
- Burlington-Keokuk Limestone: Mississippian, Osagean Series
- Mississippian, Kinderhookian Series
- Mississippian, Chesterian Series
- Devonian System undifferentiated
- Ordovician, Cotter & Jefferson City

Washburn Prairie Dye Trace

- Introduction Station
- Detect Station

The introduction point of the dye trace is a sinkhole located in the Burlington-Keokuk formation and the detection point is located in the Ozark Aquifer. See Figure Q-1 for details.

Data Source:
1. County Boundaries - ESRI gis/rest/services/USA_Counties/FeatureServer

2. Geologic Structures: Missouri Department of Natural Resources, Structures - faults, folds, and other related tectonic structures. 03-24-2010

3. Bedrock Geology: U.S. Geological Survey, Preliminary Integrated Geologic Map Databases for the United States Central States -The State of Missouri 2005. Issue Identification: 2005-1351

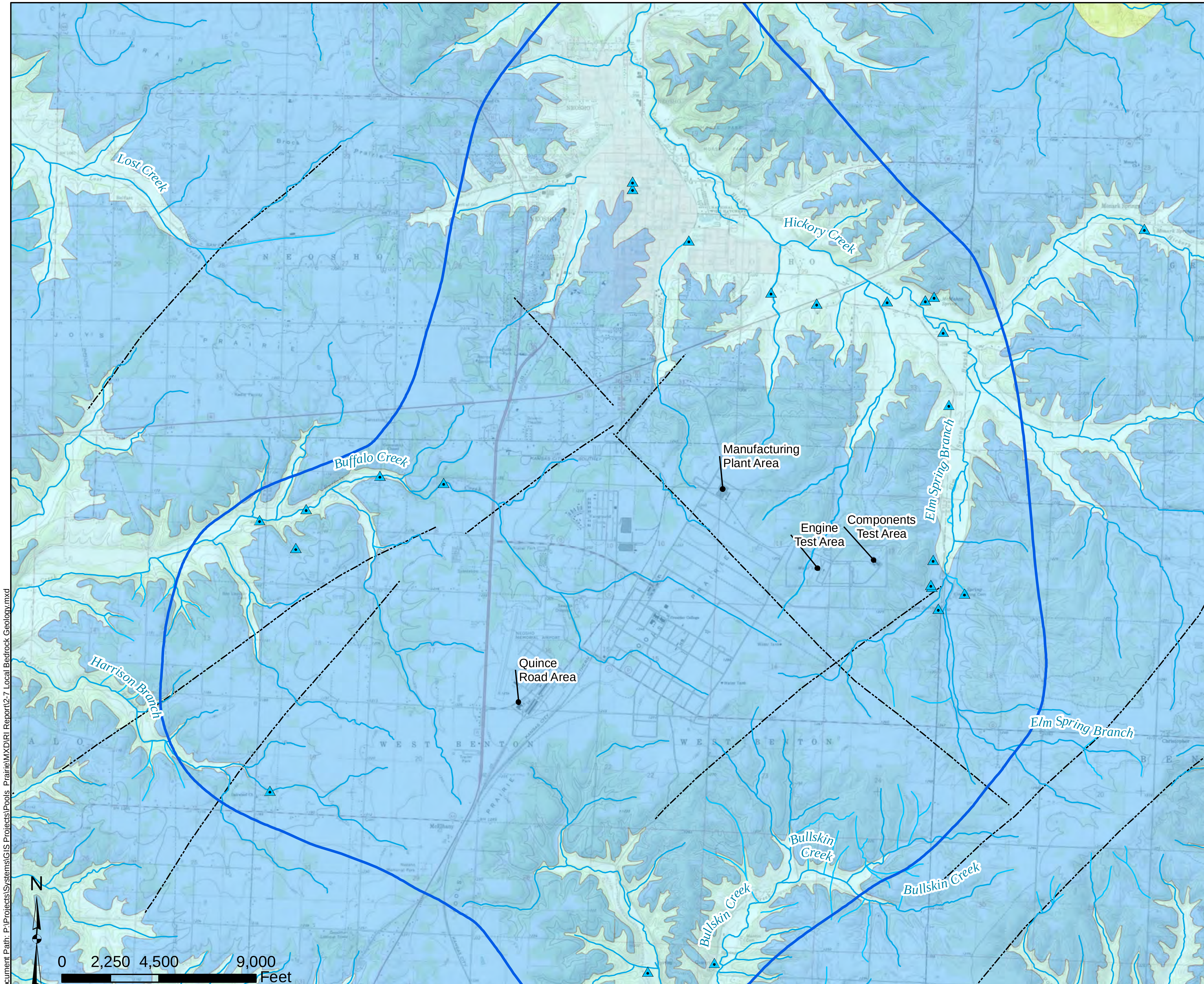
4. Dye Trace: Miller and Vandike, Groundwater Resources of Missouri, Water Resources Report Number 46, Volume II, 1997.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Regional Bedrock Geology
and Geologic Structures

DRN. BY: IJP CHKD. BY: HB 12/7/2015	AECOM	FIG. NO. 2-3

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\2-3 Regional Geology.mxd



Phase 1 RI Study Area

Phase 1 RI Sampled Spring

Streams

Bedrock Lineaments

Bedrock Geology Map Units

Warsaw Formation: Mississippian, Meramecian Series

Limestone and chert (up to 70 percent). The Warsaw resembles the underlying Burlington-Keokuk Limestone; isolated outcrops are difficult to identify with certainty unless the Short Creek Oolite is exposed. The Warsaw is covered by a thick blanket of cherty residuum.

Burlington-Keokuk Limestone: Mississippian, Osagean Series

Limestone and chert (up to 70 percent). Bedrock is jointed; springs, caves, and losing streams are present. In most places weathering has changed the upper portion of the formation into cherty residuum (the McDowell surficial material unit.)

Pennsylvanian, Cherokee, Krebs

Data Source:
1. U.S. Geological Survey, Preliminary Integrated Geologic Map Databases for the United States Central States -The State of Missouri 2005. Issue Identification: 2005-1351

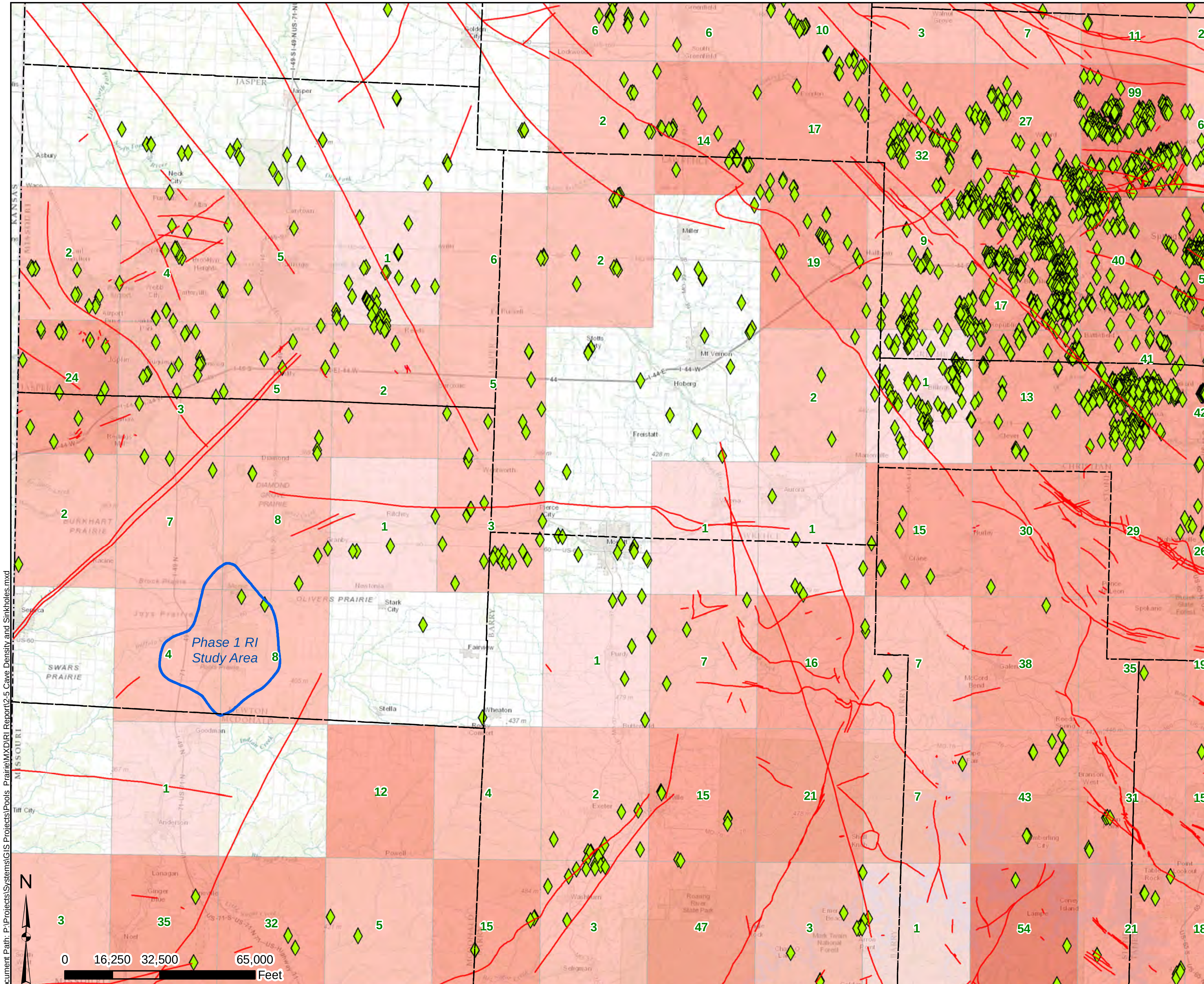
2. Legend text from Bedrock Geologic Map of the Neosho East 7.5' Quadrangle, McDowell and Newton Counties, Missouri by John W. Whitfield, 1999

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Phase 1 RI Study Area Bedrock Geology

DRN. BY: IJP CHKD. BY: HB 11/2/2015	AECOM	FIG. NO. 2-4

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\2-7 Local Bedrock Geology.mxd



Phase 1 RI Study Area
Geologic Structures
Sinkhole Points

Cave Density

1 cave
2 - 10 caves
11 - 50 caves
51 - 100 caves
101 - 300 caves

Notes:
1. Numbers shown on map are the number of caves in each 1:24,000 scale U.S. Geological Survey quadrangle.

Data Source:
1. County Boundaries - ESRI
gis/rest/services/USA_Counties/FeatureServer

2. Geologic Structures: Missouri Department of Natural Resources, Structures - faults, folds, and other related tectonic structures.
03-24-2010

3. Cave Density: Missouri Department of Natural Resources, Missouri Geological Survey, Geological Survey Program. Cave Density. Acknowledgement is made to the Missouri Speleological Society for the known cave locations.
06-09-2006

4. Sinkholes: Missouri Department of Natural Resources, Missouri Geological Survey, Geological Survey Program, Environmental Geology Section. Sinkholes.
10-15-2014

Pools Prairie Superfund Site
Newton County, Missouri

PROJECT NO.
60419811

Regional Cave Density
and Sinkhole Presence

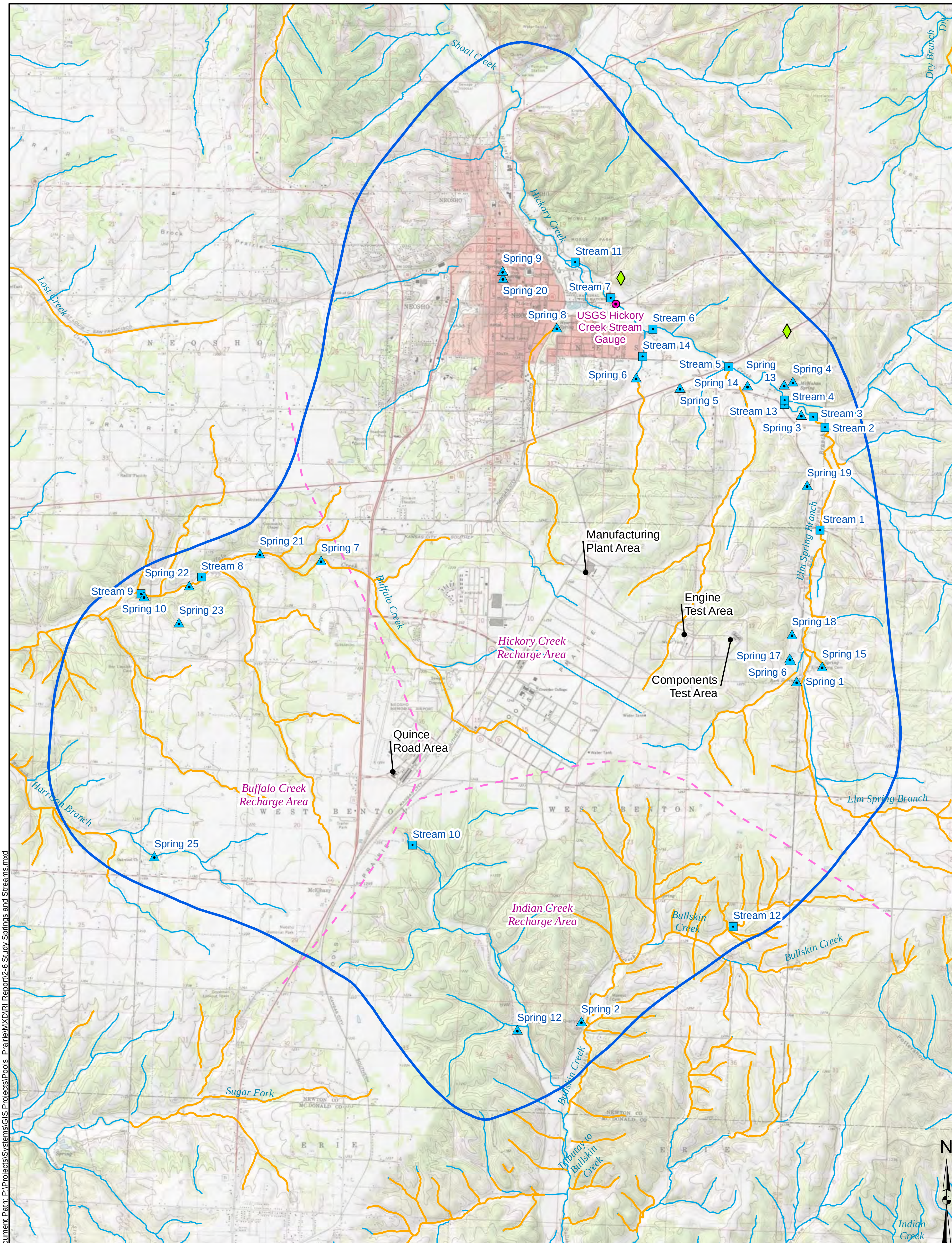
DRN. BY: IJP
CHKD. BY: HB
12/1/2015

AECOM

FIG. NO.
2-5

Document Path: P:\Projects\Systems\GIS Projects\Pools Prairie\MXD\RI Report\2-5 Cave Density and Sinkholes.mxd

Service Layer Credits: Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\2-6 Study Springs and Streams.mxd

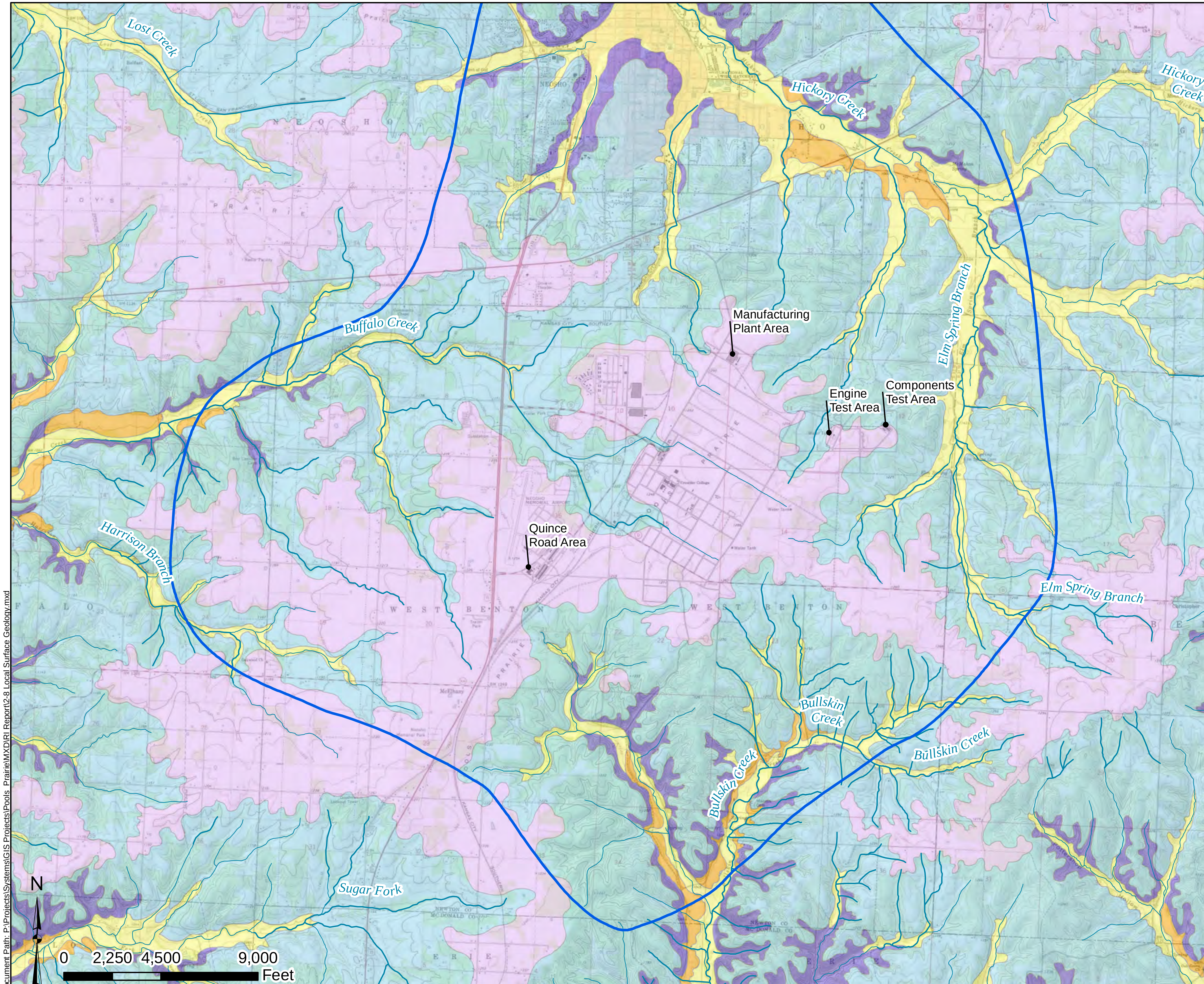
USGS Hickory Creek Gauge
Sinkhole Points
Inferred Recharge Area
Phase 1 RI Sampled Spring
Losing Stream
Phase 1 RI Study Area
Phase 1 RI Sampled Stream

0 2,250 4,500 9,000 Feet

Data Source:
1. Losing streams and gaining streams: Missouri Department of Natural Resources, Missouri Geological Survey, Geological Survey Program, Environmental Geology Section, 09/11/13. Two additional streams are included as losing streams based on their designation as such in dye trace studies: the stream north of the MPA (with Spring 6) and the stream that passes through the ETA area (Vandike and Brookshire 1996, Ozark Underground Lab 1997).

2. Other locals streams provided by the USGS National Hydrology Dataset, NHDFlowline

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Phase 1 RI Sampled Springs and Streams	
DRN. BY: IJP CHKD. BY: HB 12/1/2015	FIG. NO. 2-6



Phase 1 RI Study Area

Surface Geologic Units

Colluvium

Cherty clay and silt colluvium that accumulated at the base of slopes and formed gentle sloping fans that extend into the floodplains of creeks and small valleys.

Shallow or Exposed Bedrock

Steep slope covered by cherty colluvium, bedrock crops out or is near the surface.

Residuum with Fragipan

Thick, cherty residuum comprised of interbedded layers of relic chert and reddish-brown, silty clay.

Terrace

Silt, clay and chert gravel. Silt and clay are derived from alluvium and colluvium. Terrace deposits contain lenticular beds of gravel interbedded with silt and clay. The amount and size of chert gravel in terraces increases with depth.

Alluvium and Related

Comprised of rounded to angular chert gravels and cobbles mixed with silt, sand, and clay. The outer margin of the colluvial fans grade or interfinger into alluvium to terraces.

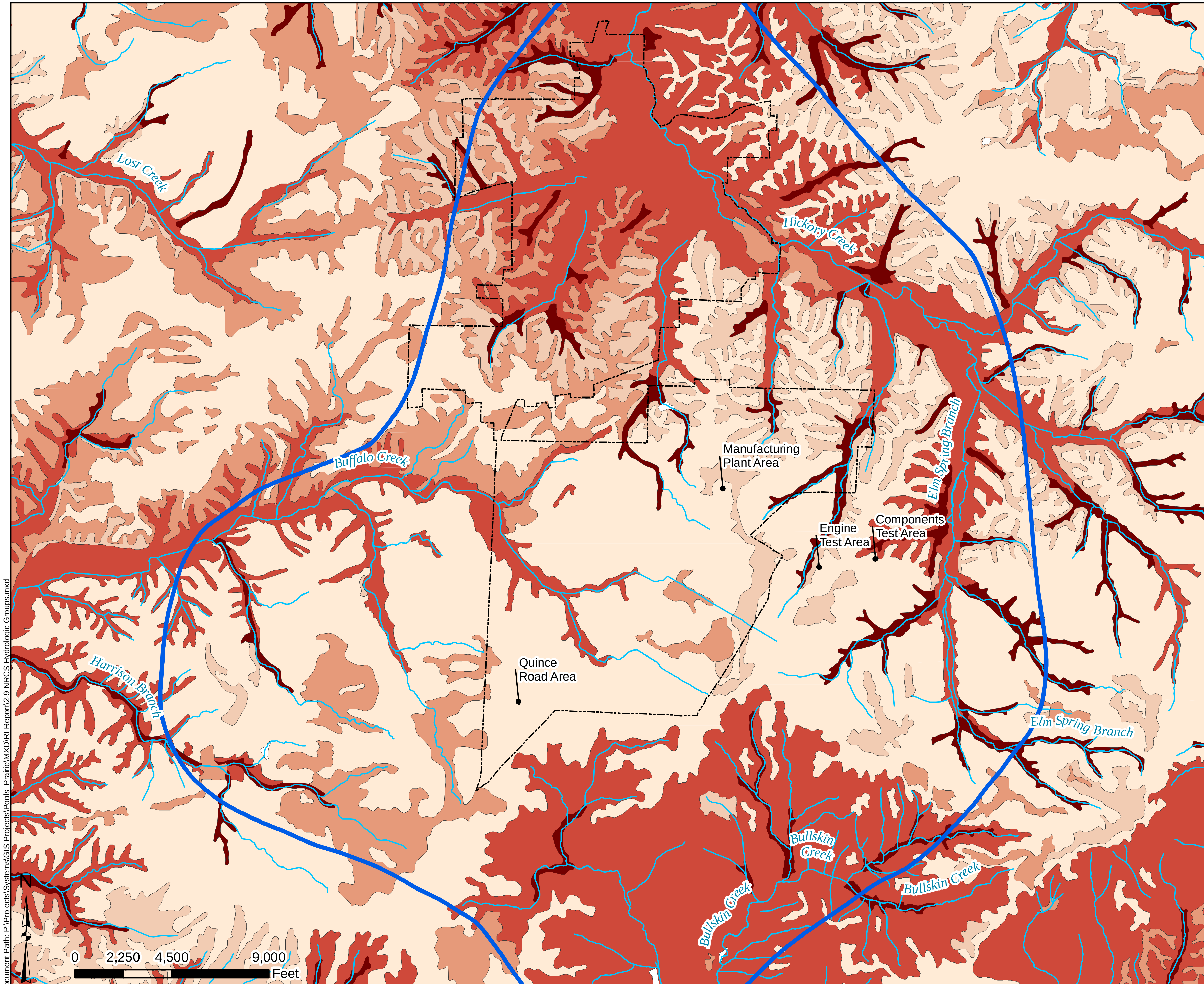
Data Source:
1. Missouri Department of Natural Resources (MDNR), Missouri Geological Survey, Digitized from the Surficial Materials Map of Missouri by John W. Whitfield, 1999

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Phase 1 RI Study Area Surficial Geology

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 2-7

Document Path: P:\Projects\Systems\GIS Projects\Pools Prairie\MXD\RI Report\2-8 Local Surface Geology.mxd



Phase 1 RI Study Area

Neosho City Limits

Hydrologic Soil Group

Hydrologic soil groups were developed by the Natural Resources Conservation Service (NRCS), and are based upon measured rainfall, runoff, and infiltrometer data.

Unclassified

A

Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil.

B

Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded.

B/D

The first letter applies to the drained condition and the second applies to the saturated condition.

C

Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted.

C/D

The first letter applies to the drained condition and the second applies to the saturated condition.

D

Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted.

Data Source:
1. Soil Survey Staff. The Gridded Soil Survey Geographic Database for Missouri. United States Department of Agriculture, Natural Resources Conservation Service. Available online at http://datagateway.nrcs.usda.gov/. December 1, 2014 (FY2015 official release).

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Hydrologic Soil Groups

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 2-8

Phase 1 RI Study Area

Hydrologic Soil Group A

Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil.

Surface Geologic Units

Colluvium

Cherty clay and silt colluvium that accumulated at the base of slopes and formed gentle sloping fans that extend into the floodplains of creeks and small valleys.

Shallow or Exposed Bedrock

Steep slope covered by cherty colluvium, bedrock crops out or is near the surface.

Residuum with Fragipan

Thick, cherty residuum comprised of interbedded layers of relic chert and reddish-brown, silty clay.

Terrace

Silt, clay and chert gravel. Silt and clay are derived from alluvium and colluvium. Terrace deposits contains lenticular beds of gravel interbedded with silt and clay. The amount and size of chert gravel in terraces increases with depth.

Alluvium and Related

Cherty clay and silt colluvium that accumulated at the base of slopes and formed gentle sloping fans that extend into the floodplains of creeks and small valleys.

Data Source:
1. U.S. Geological Survey, Preliminary Integrated Geologic Map Databases for the United States Central States -The State of Missouri 2005. Issue Identification: 2005-1351

2. Missouri Department of Natural Resources Missouri Geological Survey, Digitized from the Surficial Materials Map of Missouri by John W. Whitfield, 1999

Pools Prairie Superfund Site
Newton County, Missouri

PROJECT NO. 60419811

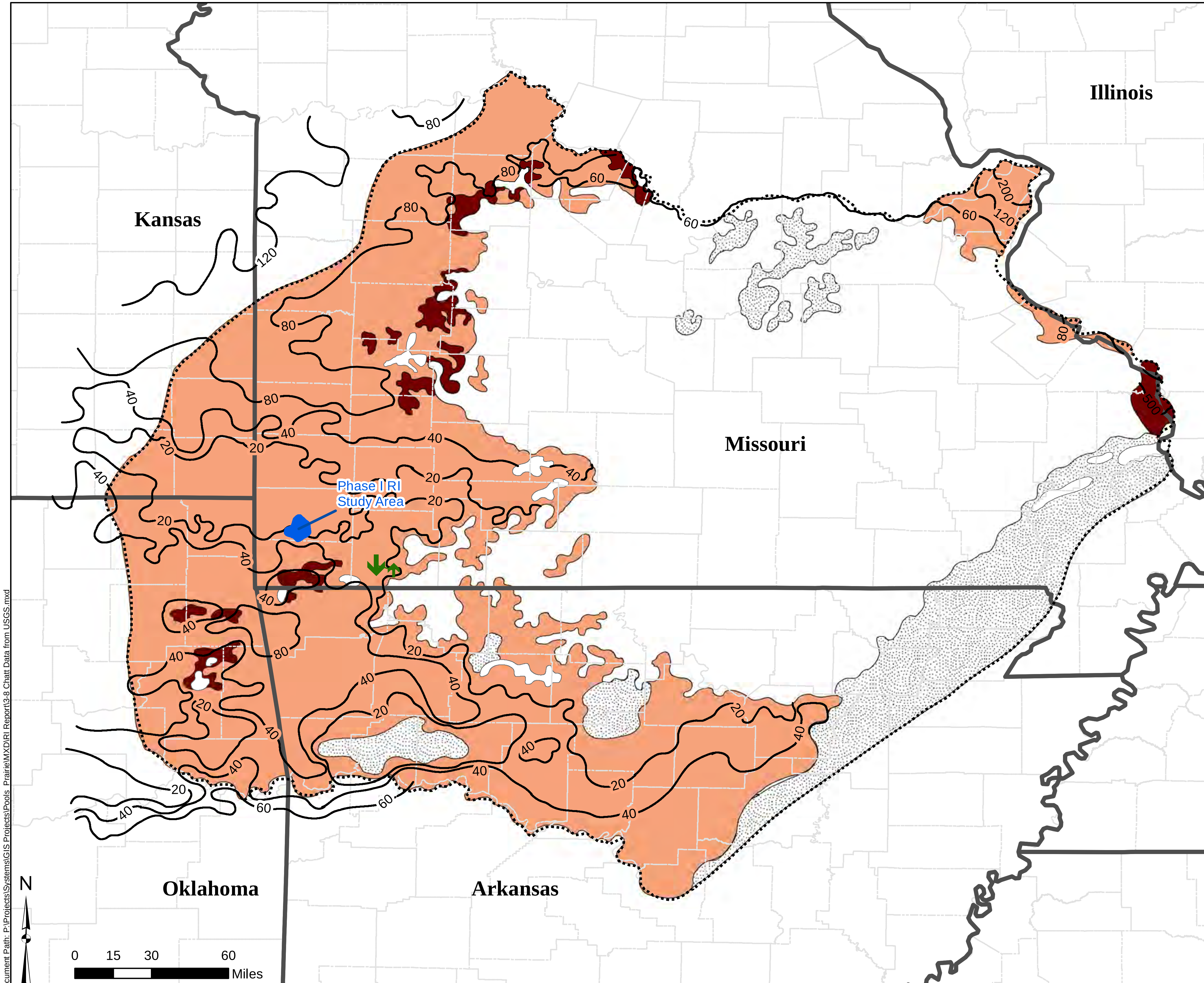
Phase 1 RI Study Area Surficial Geology with High Conductivity Soils

DRN. BY: IJP
CHKD. BY: HB
12/1/2015

AECOM

FIG. NO. 2-9

Document Path: P:\Projects\Systems\GIS Projects\Pools Prairie\MXD\RI Report\2-10 Local Geo and NRCS High Conductivity.mxd



Phase 1 RI Study Area
Line of Equal Thickness
Boundary of Imes and Emmett Study Area
Areal Extent of Confining Unit in Subsurface
Area Where Confining Unit is Missing in Subsurface
Outcrop Area of Confining Unit
County Boundaries
State Boundaries

Washburn Prairie Dye Trace

Introduction Point
Detect Station

To view Washburn Prairie Dye Trace in more detail, refer to figure 3-3 and Appendix Q.

Data Source:
1. Adapted from Imes and Emmett 1994. Locations are approximate.

2. Dye Trace: Miller and Vandike, Groundwater Resources of Missouri, Water Resources Report Number 46, Volume II, 1997.

Pools Prairie Superfund Site
Newton County, Missouri

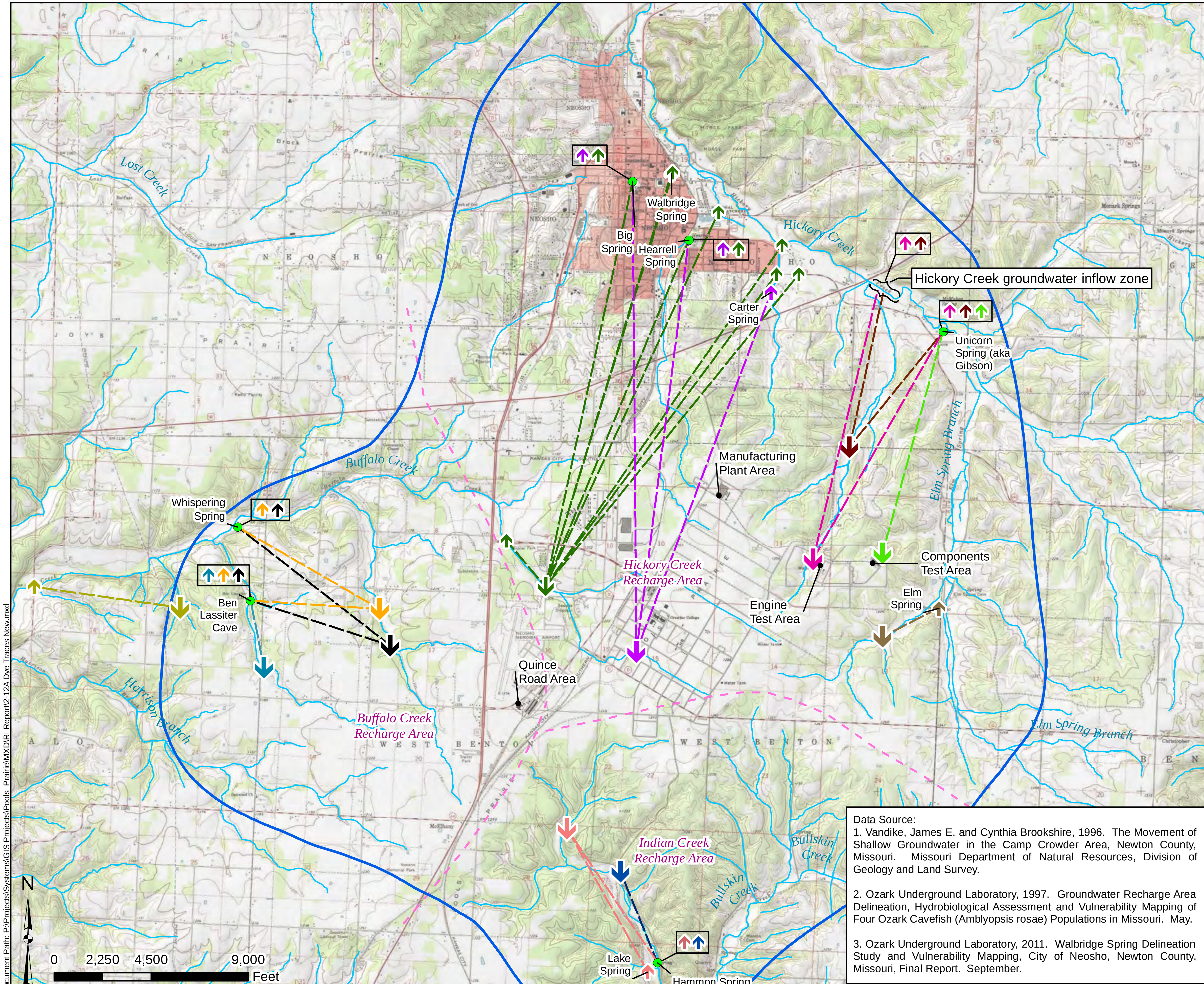
PROJECT NO. 60419811

Regional Extent and Thickness of the Ozark Confining Unit

DRN. BY: IJP
CHKD. BY: HB
9/9/2015

FIG. NO. 2-10

Document Path: P:\Projects\Systems\GIS Projects\Pools Prairie\MXD\RI Report\3-8 Chatt Data from USGS.mxd



Data Source:
1. Vandike, James E. and Cynthia Brookshire, 1996. The Movement of Shallow Groundwater in the Camp Crowder Area, Newton County, Missouri. Missouri Department of Natural Resources, Division of Geology and Land Survey.

2. Ozark Underground Laboratory, 1997. Groundwater Recharge Area Delineation, Hydrobiological Assessment and Vulnerability Mapping of Four Ozark Cavefish (Amblyopsis rosae) Populations in Missouri. May.

3. Ozark Underground Laboratory, 2011. Walbridge Spring Delineation Study and Vulnerability Mapping, City of Neosho, Newton County, Missouri, Final Report. September.

DT-4 (Buffalo Creek Tributary Trace 3)
- Detect Station
- Introduction Point

DT-2 (Buffalo Creek Tributary Trace 2)
- Detect Station
- Introduction Point

DT-1 (Buffalo Creek Tributary Trace)
- Detect Station
- Introduction Point

CC-7 (Main Gate Trace)
- Detect Station
- Introduction Point

CC-6 (Firing Range Trace)
- Detect Station
- Introduction Point

CC-5 (Component Testing Area Trace)
- Detect Station
- Introduction Point

CC-4 (Rocket Engine Test Stand Trace)
- Detect Station
- Introduction Point

CC-2 (Hickory Creek Trace)
- Detect Station
- Introduction Point

CC-1 (Elm Spring Trace)
- Detect Station
- Introduction Point

Ben Lassiter Cave Branch Trace
- Detect Station
- Introduction Point

11-02 (Buffalo Creek Trace)
- Detect Station
- Introduction Station

Hammon Spring Trace
- Detect Station
- Introduction Point

Phase 1 RI Study Area

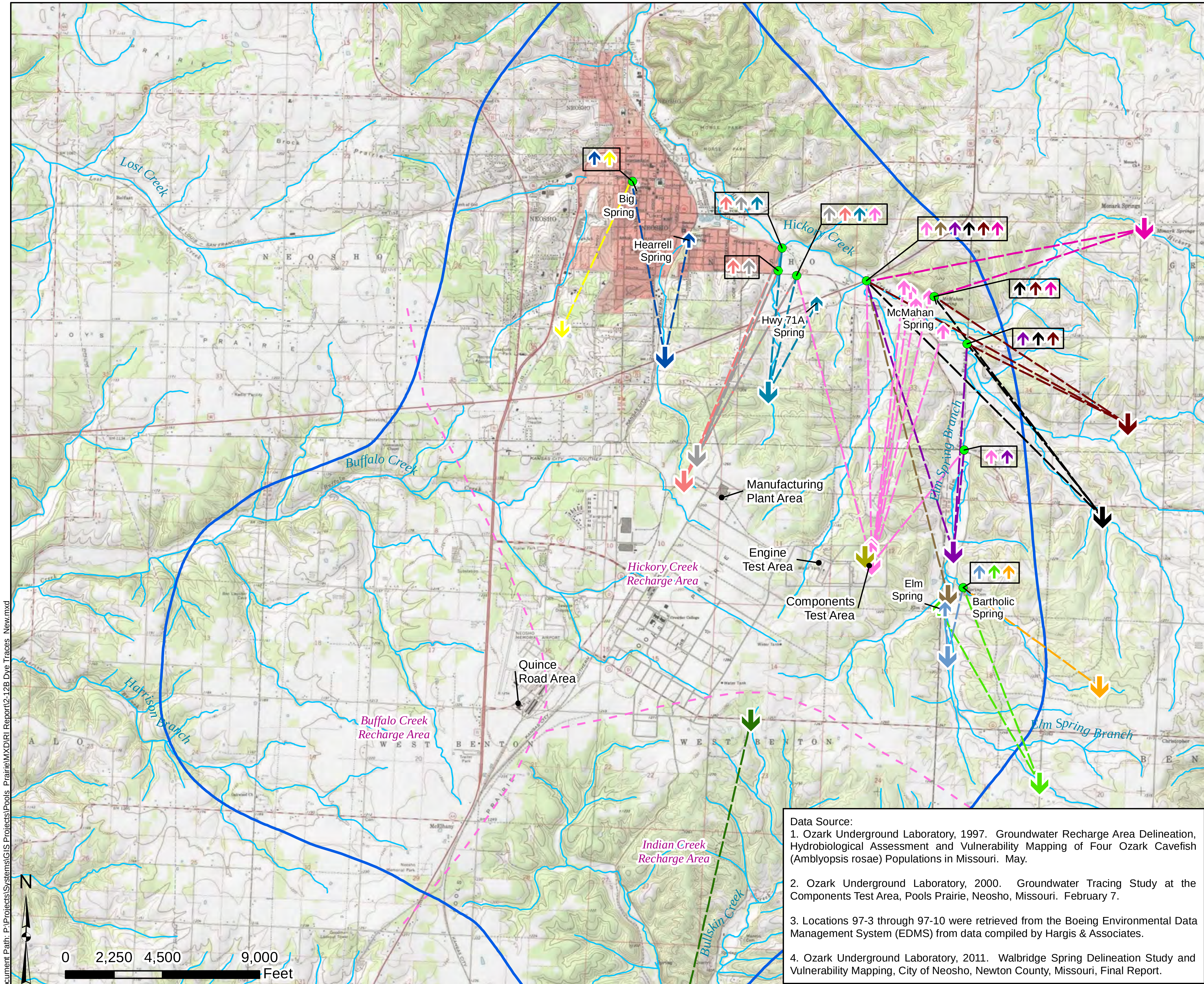
Inferred Recharge Area

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Historical Dye Trace Study Results

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 2-11A

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\2-12A Dye Traces New.mxd



11-01 (Oriental Restaurant Trace)
- Detect Station
- Introduction Station

99-01 (MW15 Trace)
- Introduction Point

99-03 (MW13 Trace)
- Detect Station
- Introduction Point

96-14 (Monark Trace)
- Detect Station
- Introduction Point

96-15 (MDC Trace)
- Detect Station
- Introduction Point

96-16 (Highway 71A Trace)
- Detect Station
- Introduction Point

97-01 (Old Mine 1 Trace)
- Detect Station
- Introduction Point

97-02 (Industry Area 1 Trace)
- Detect Station
- Introduction Point

97-03 (Parallel Streams Trace)
- Detect Station
- Introduction Point

97-04 (Half Mile North of MDC Barn Trace)
- Detect Station
- Introduction Point

97-05 (Elm Spring Branch Trace)
- Detect Station
- Introduction Point

97-06 (Section 35 Trace)
- Detect Station
- Introduction Point

97-07 (Highway D Trace)
- Detect Station
- Introduction Point

97-08 (Elm Spring Cemetery Trace)
- Detect Station
- Introduction Point

97-09 (Section 19 Trace)
- Detect Station
- Introduction Point

97-10 (Gibson Spring Branch Trace)
- Detect Station
- Introduction Point

Phase 1 RI Study Area

Inferred Recharge Area

Data Source:
1. Ozark Underground Laboratory, 1997. Groundwater Recharge Area Delineation, Hydrobiological Assessment and Vulnerability Mapping of Four Ozark Cavefish (Amblyopsis rosae) Populations in Missouri. May.

2. Ozark Underground Laboratory, 2000. Groundwater Tracing Study at the Components Test Area, Pools Prairie, Neosho, Missouri. February 7.

3. Locations 97-3 through 97-10 were retrieved from the Boeing Environmental Data Management System (EDMS) from data compiled by Hargis & Associates.

4. Ozark Underground Laboratory, 2011. Walbridge Spring Delineation Study and Vulnerability Mapping, City of Neosho, Newton County, Missouri, Final Report.

Pools Prairie Superfund Site
Newton County, Missouri

PROJECT NO. 60419811

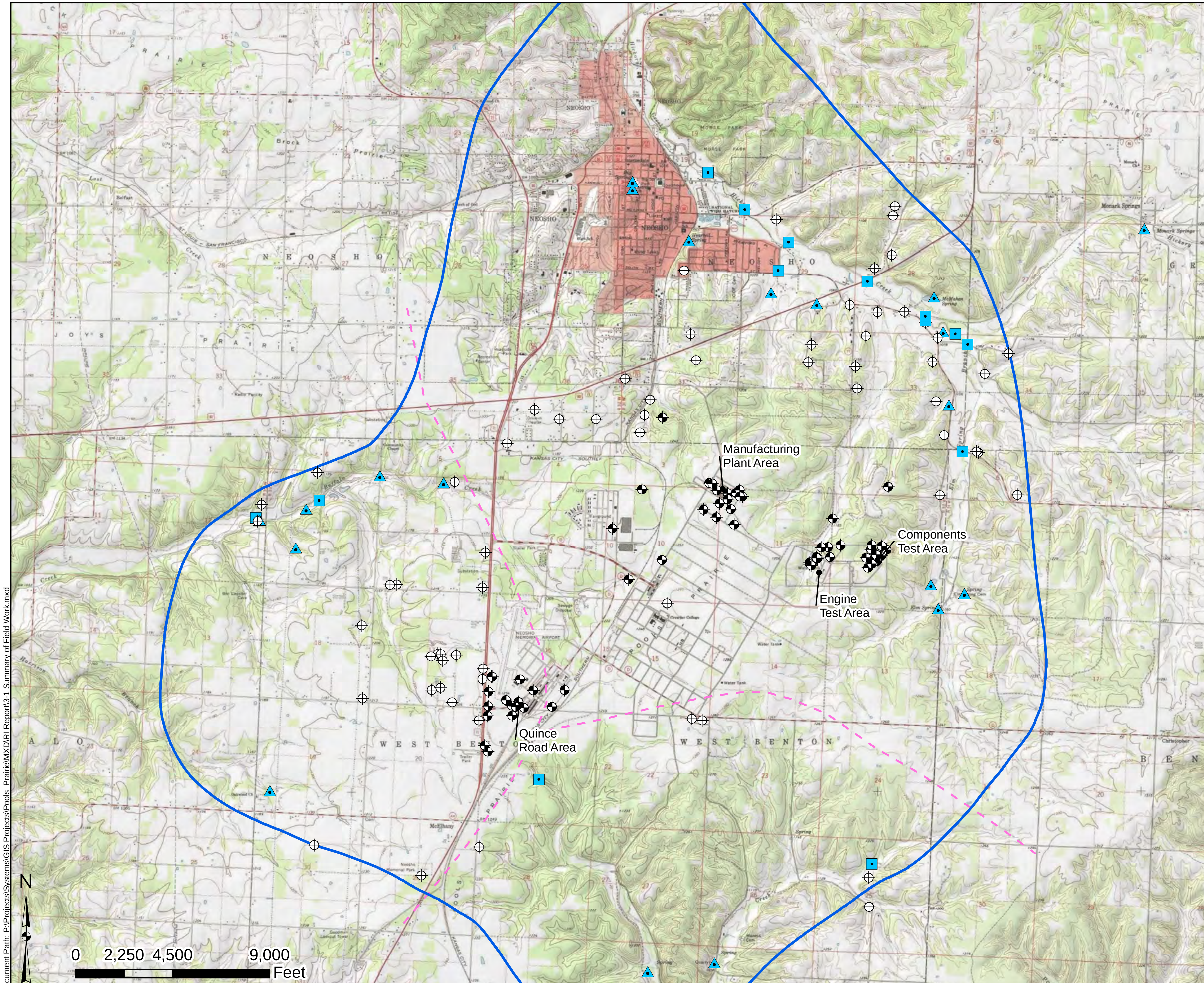
Historical Dye Trace Study Results

DRN. BY: IJP
CHKD. BY: HB
12/1/2015

AECOM

FIG. NO. 2-11B

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\2-12B Dye Traces_New.mxd



Spring Water Sample
Stream Water Sample
Monitoring Well Water Sample
Private Water Sample
Phase 1 RI Study Area
Inferred Recharge Area

Data Source:
1. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

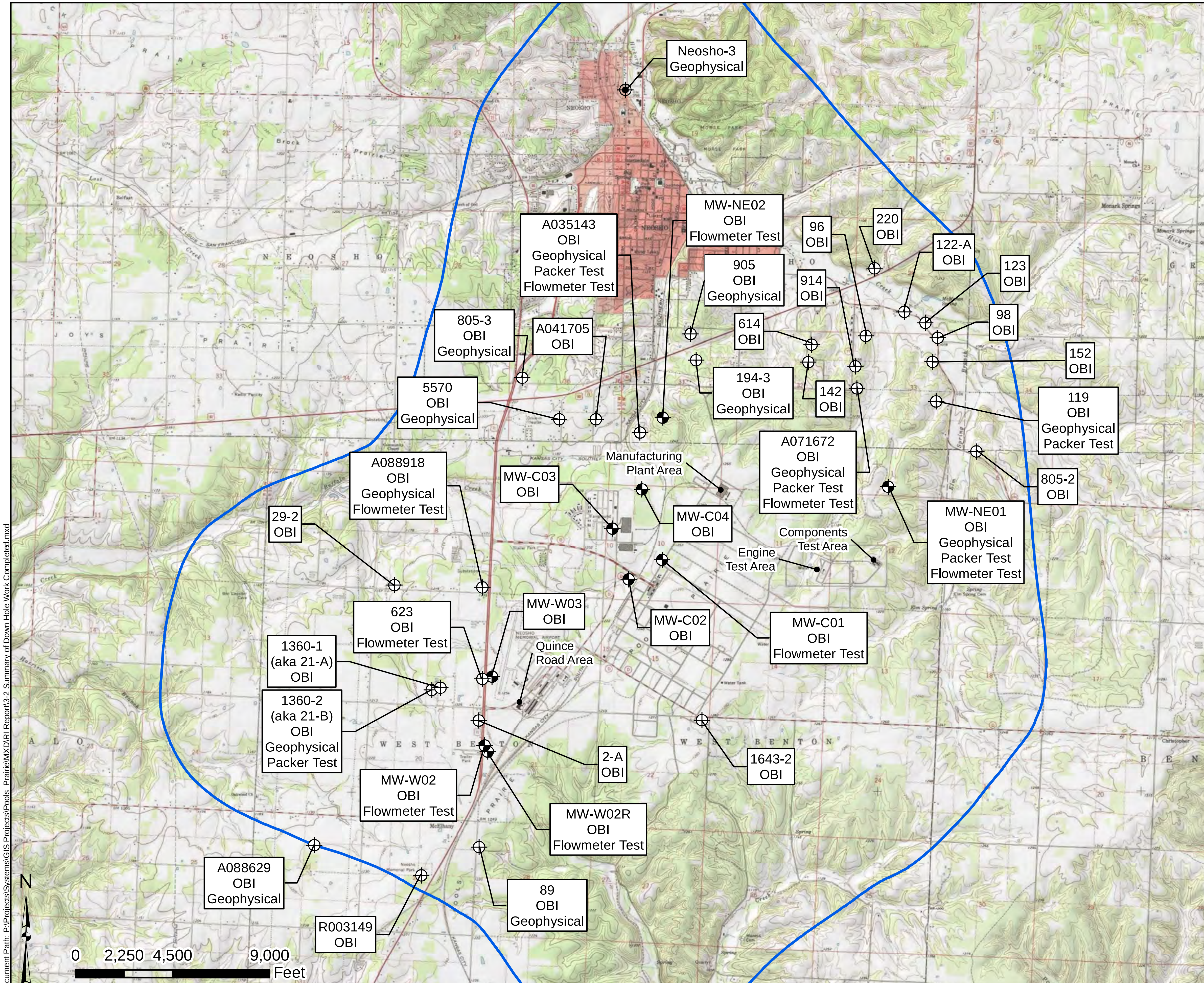
Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Summary of Phase 1 RI Sampling Work Completed

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 3-1

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\3-1 Summary of Field Work.mxd

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed



Down Hole Work Completed

Well Type

- Other Well
- Monitoring Well
- Private Well
- Phase 1 RI Study Area

Notes:
1. Optical borehole images (OBIs) are 360-degree images of the continuous borehole wall created by a specialized camera that functions both in air and under water.

2. Geophysical analysis included evaluation of fracture density and orientation, fracture ranking based on flow potential, natural gamma testing, electrical resistivity, and/or 3-arm caliper testing. OBI data was used for the fracture analysis.

3. Flowmeter tests involved pulling a device capable of measuring flow from 0.02 to 10 gallons/minute through the borehole, under both ambient and pumping conditions.

4. Both single and straddle packer testing was conducted. Packer testing involves inserting an inflatable bladder(s) equipped with pressure transducers into a well to allow for separation of zones and measurement of water pressure in different zones. Single packer testing was done in crossover wells (wells open to both the Springfield Plateau and Ozark Aquifers), with the packer placed at the Ozark Confining Unit. This allowed for measurement of potentiometric conditions in both the Springfield Plateau and Ozark Aquifers. A straddle packer includes two bladders, in this case, separated by 4 ft. This allows for testing of a specific 4-ft zone, in addition to the zones both above and below the packer assembly. Packer test results are summarized in Table 3-3.

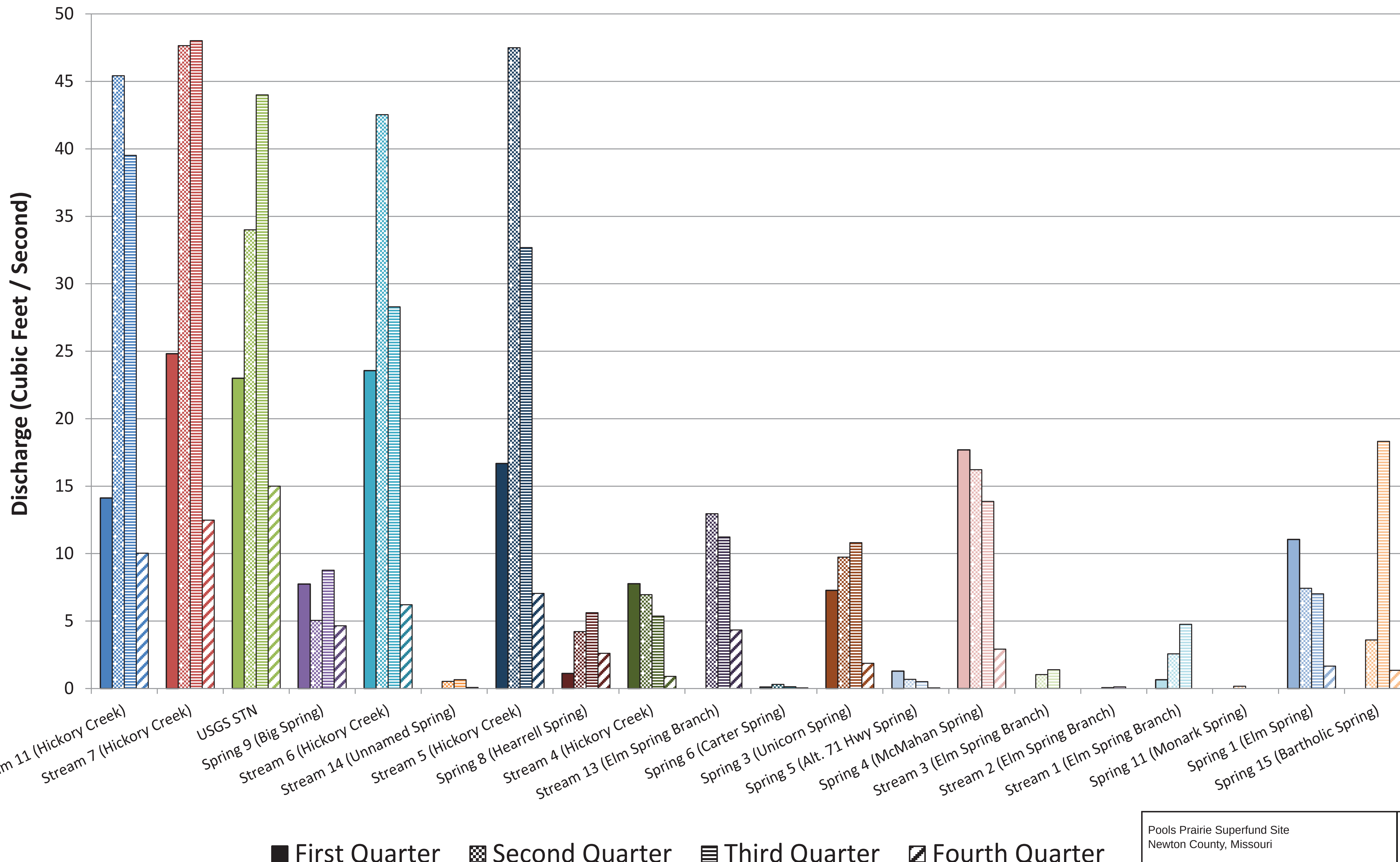
Data Source:
1. Phase 1 RI Sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Summary of Down Hole Work Completed

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 3-2

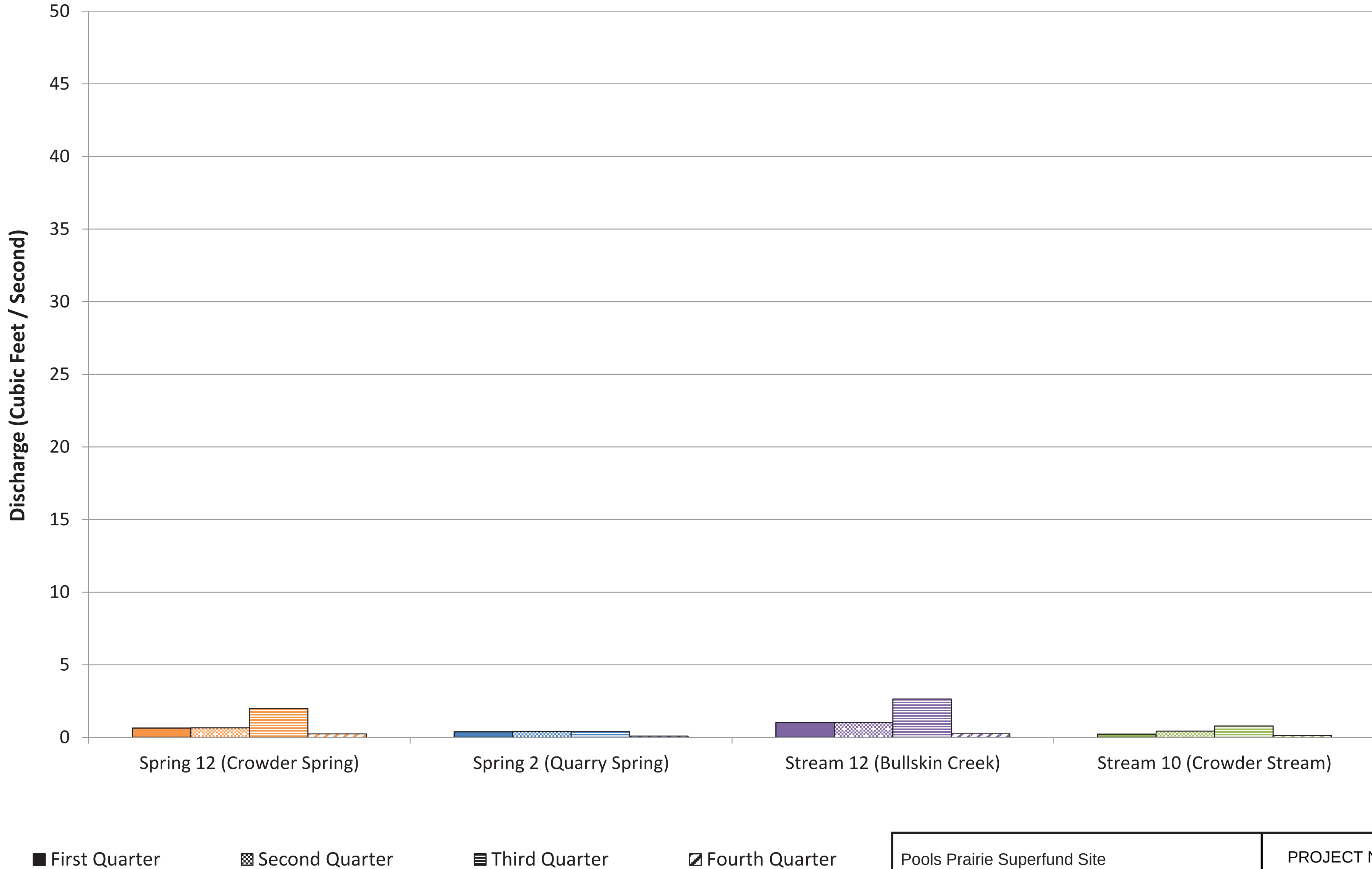
Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\3-2 Summary of Down Hole Work Completed.mxd



Data Source:
Data collected by URS/AECOM in 2013.

Notes:
1. Locations of sampling points are shown in Figure 2-6. Spring and stream flows in the Hickory Creek recharge area are much larger than those in Buffalo and Indian Creeks. Springs and streams show significant seasonal variation, with low flows generally in the fall and high flow usually in spring or summer.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Hickory Creek Recharge Area 2013 Stream and Spring Discharge Rates	
DRN. BY: LMF CHKD. BY: HRB 7/2/15	FIG. NO. 3-3A



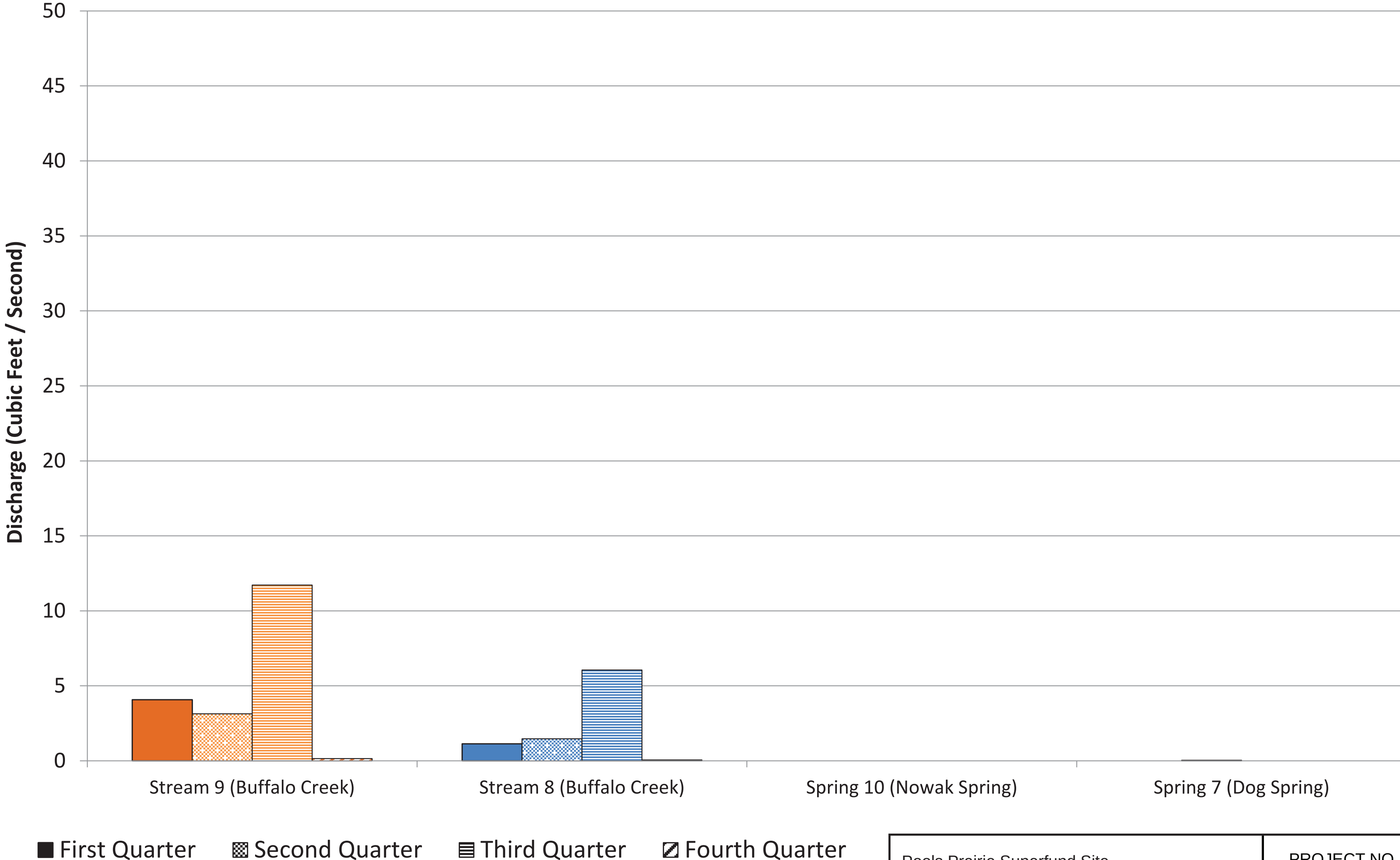
Notes:

1. Locations of sampling points are shown in Figure 2-6. Spring and stream flows in the Indian Creek recharge area are small compared to Hickory Creek. Only two springs with measurable flow were found.

Data Source:
Data collected by URS/AECOM in 2013.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Indian Creek Recharge Area 2013 Stream and Spring Discharge Rates	
DRN. BY: LMF CHKD. BY: HRB 7/2/15	FIG. NO. 3-3B

AECOM

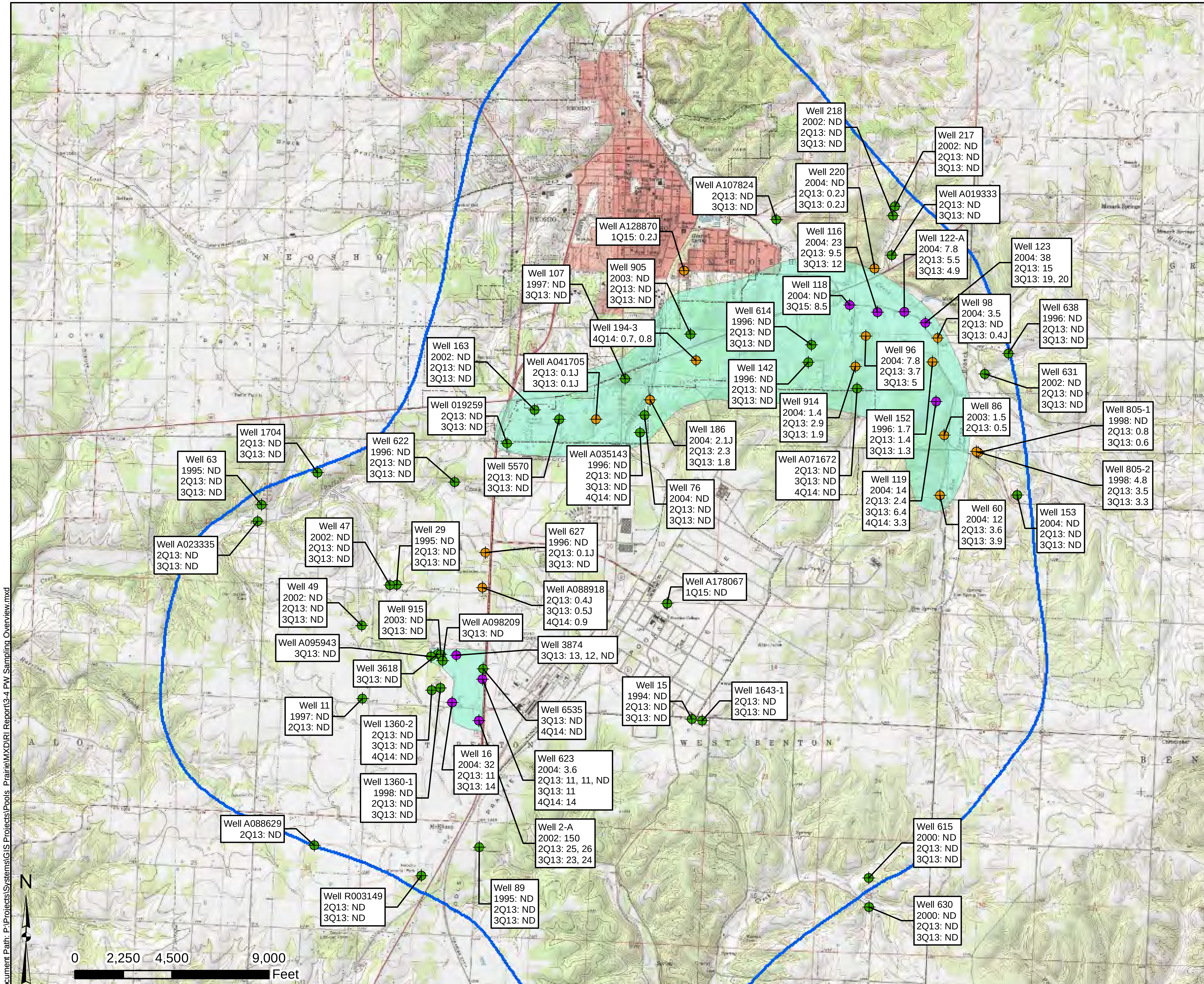


Notes:

1. Locations of sampling points are shown in Figure 2-6. Spring and stream flows in the Buffalo Creek recharge area are small compared to Hickory Creek. No to negligible flow was found in the springs.

Data Source:
Data collected by URS/AECOM in 2013.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Buffalo Creek Recharge Area 2013 Stream and Spring Discharge Rates	
DRN. BY: LMF CHKD. BY: HRB 7/2/15 AECOM	FIG. NO. 3-3C



Phase 1 RI Sampled Private Water

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Phase 1 RI Study Area
- Area Offered City Water
- Neosho City Limits

Notes:

1. ND = Not Detected Above Detection Limit
2. J = Lab Estimated Value
3. All Concentrations in Micrograms per Liter (µg/L)
4. At Wells 623 and 3874, the 2013 ND samples were taken after carbon treatment units had been installed on the sampled spigots.

Well 012345	Well ID
2002: 0.7	2002: Most Recent Result Prior to Ph 1
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

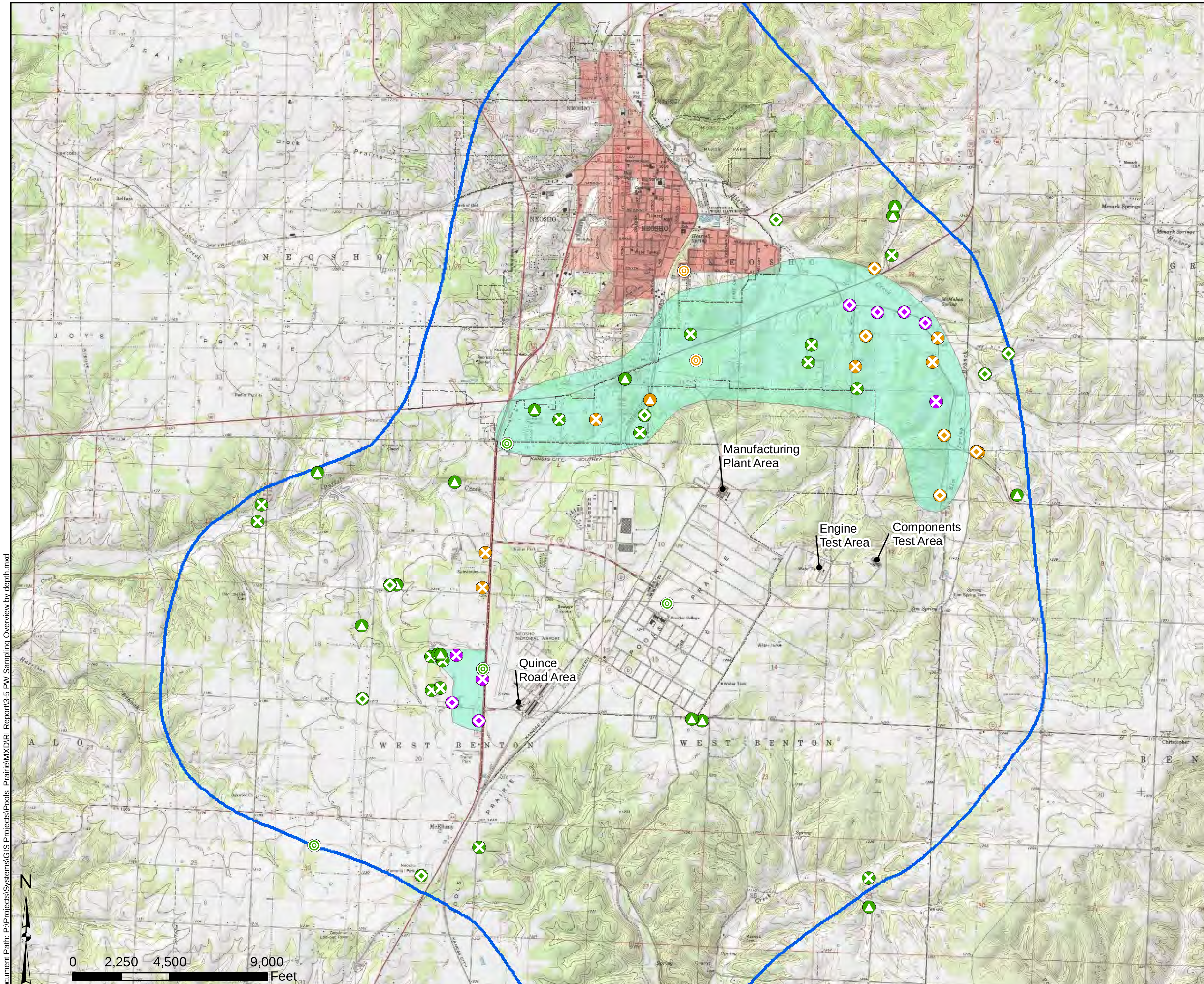
2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Phase 1 RI Private Water Sample Results

DRN. BY: IJP CHKD. BY: HB 12/4/2015	AECOM	FIG. NO. 3-4

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\3-4 PW Sampling Overview.mxd



Springfield Plateau Aquifer (SPA) Wells

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L

Ozark Aquifer Wells

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L

Aquifer Undetermined Wells

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L

Crossover Wells

(wells open to both the SPA and Ozark Aquifers)

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L

- Phase 1 RI Study Area
- Area Offered City Water
- Neosho City Limits

Data Source:
1. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

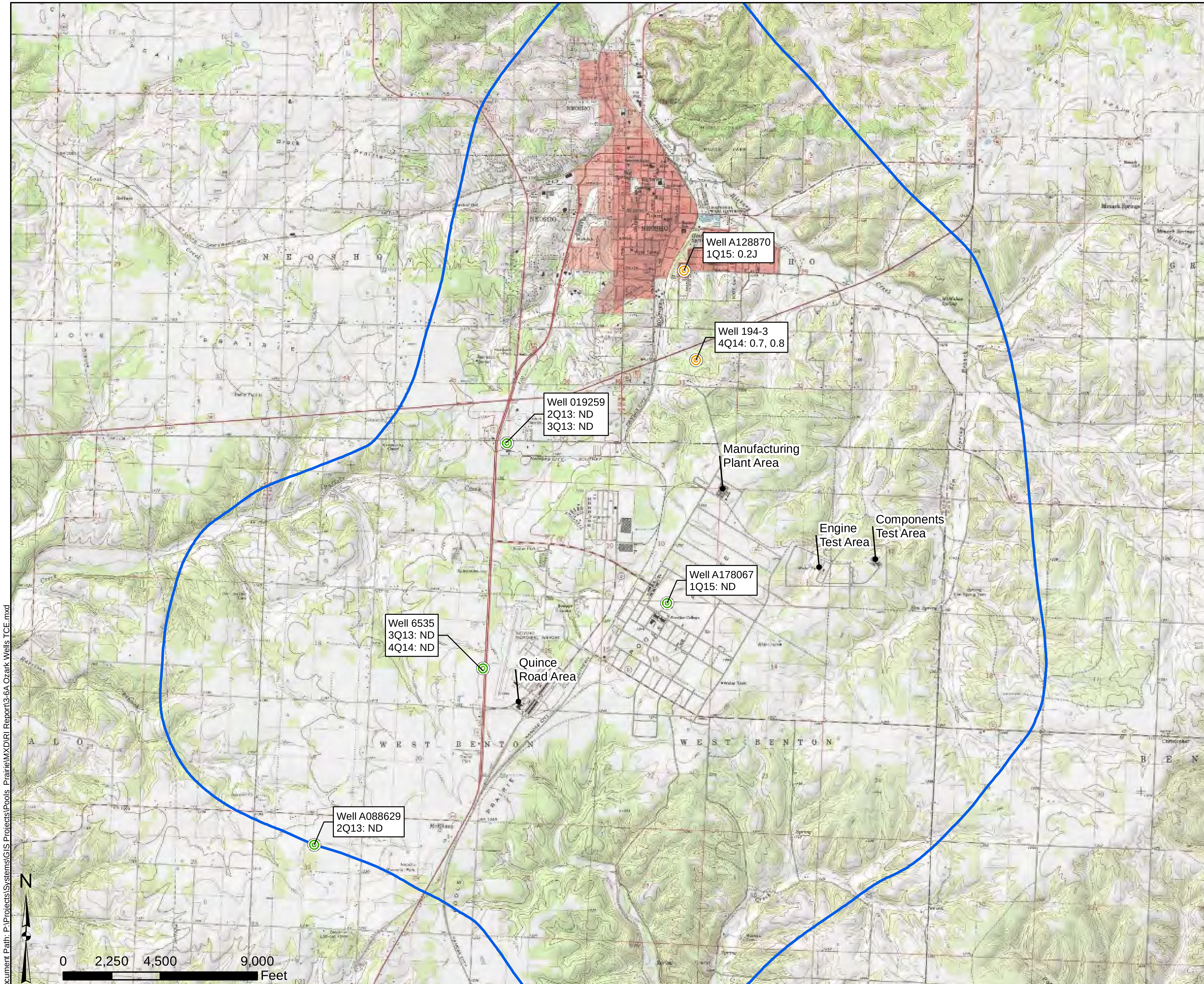
Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Phase 1 RI Sampled Private Water
Maximum Phase 1 RI TCE Concentration
by Aquifer

DRN. BY: IJP CHKD. BY: HB 2/16/2016	AECOM	FIG. NO. 3-5

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\3-5 PW Sampling Overview by depth.mxd

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed



Ozark Aquifer

Max TCE Detected, Phase 1 RI Sampling

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Phase 1 RI Study Area

Notes:

1. ND = Not Detected Above Detection Limit
2. J = Lab Estimated Value
3. All Concentrations in Micrograms per Liter (µg/L)

Well 012345	Well ID
2002: 0.7	2002: Most Recent Result Prior to Ph 1
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

Data Source:
1. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site
Newton County, Missouri

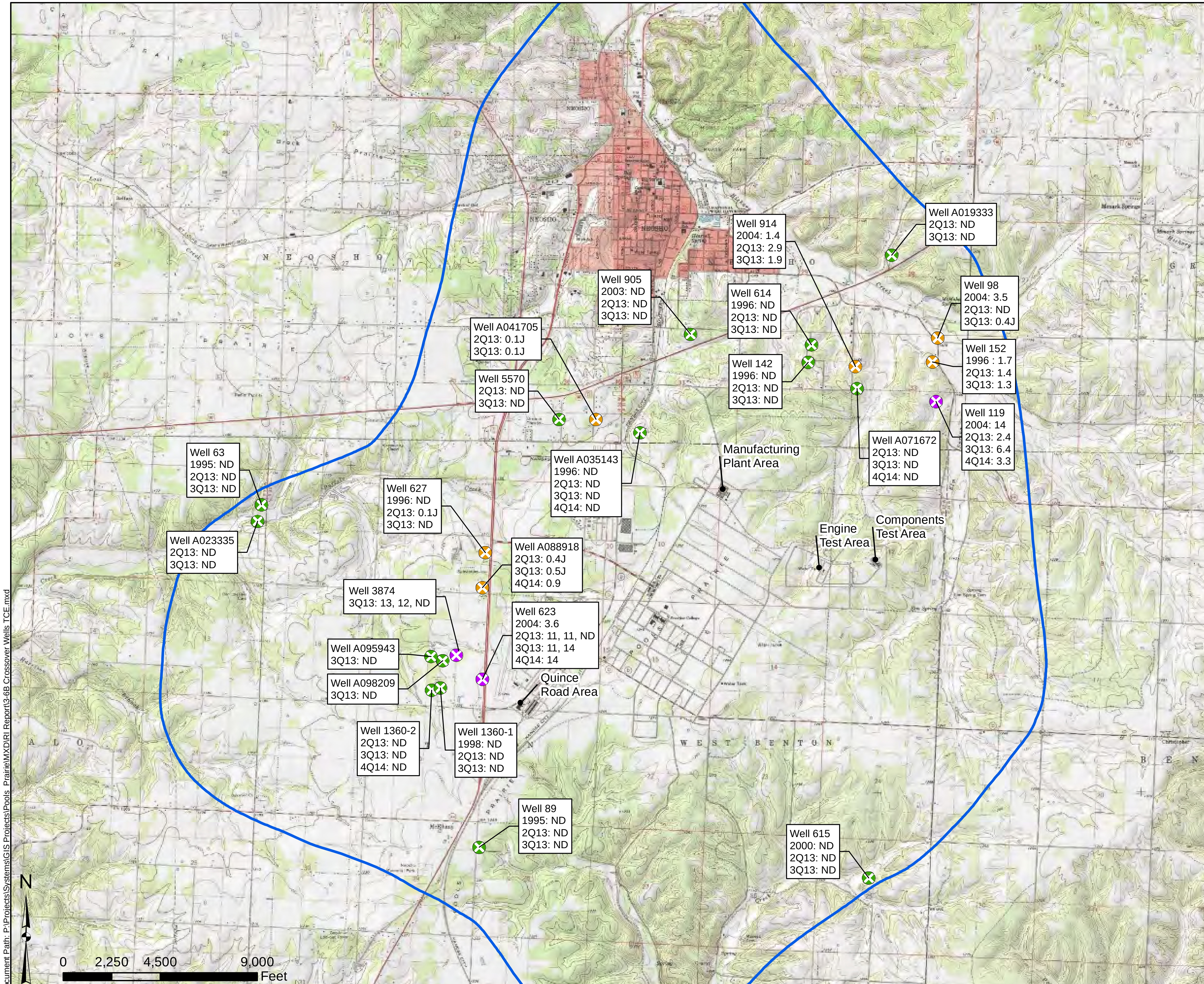
PROJECT NO.
60419811

TCE Results, Ozark Aquifer, Phase 1 RI

DRN. BY: IJP
CHKD. BY: HB
2/16/2016

AECOM

FIG. NO.
3-6A



Document Path: P:\Projects\Systems\GIS Projects\Pools Prairie\MXD\RI Report\3-6B Crossover Wells TCE.mxd

Crossover Wells (wells open to both the SPA and Ozark Aquifers)

Max TCE Detected, Phase 1 RI Sampling

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Phase 1 RI Study Area

Notes:

1. ND = Not Detected Above Detection Limit

2. J = Lab Estimated Value

3. All Concentrations in Micrograms per Liter (µg/L)

4. Some samples were taken directly from wells and some were taken from spigots.

5. At Wells 623 and 3874, the 2013 ND samples were taken after carbon treatment units had been installed on the sampled spigots.

Well 012345	Well ID
2002: 0.7	2002: Most Recent Result Prior to Ph 1
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site
Newton County, Missouri

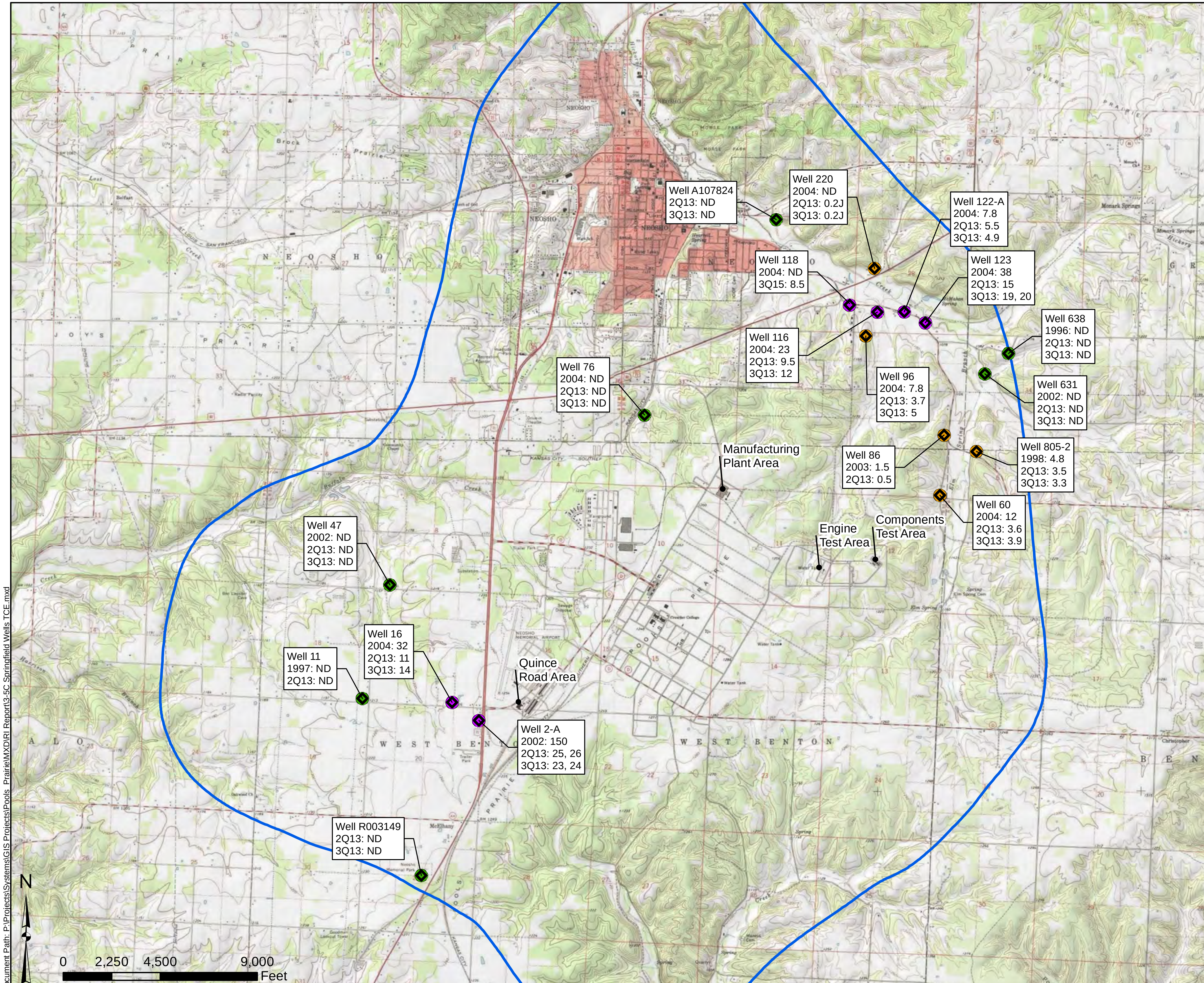
PROJECT NO.
60419811

TCE Results, Crossover Wells, Phase 1 RI

DRN. BY: IJP
CHKD. BY: HB
2/16/2016

AECOM

FIG. NO.
3-6B



Springfield Plateau Aquifer (SPA)

Max TCE Detected, Phase 1 RI Sampling

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Phase 1 RI Study Area

Notes:

1. ND = Not Detected Above Detection Limit

2. J = Lab Estimated Value

3. All Concentrations in Micrograms per Liter (µg/L)

Well 012345	Well ID
2002: 0.7	2002: Most Recent Result Prior to Ph 1
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

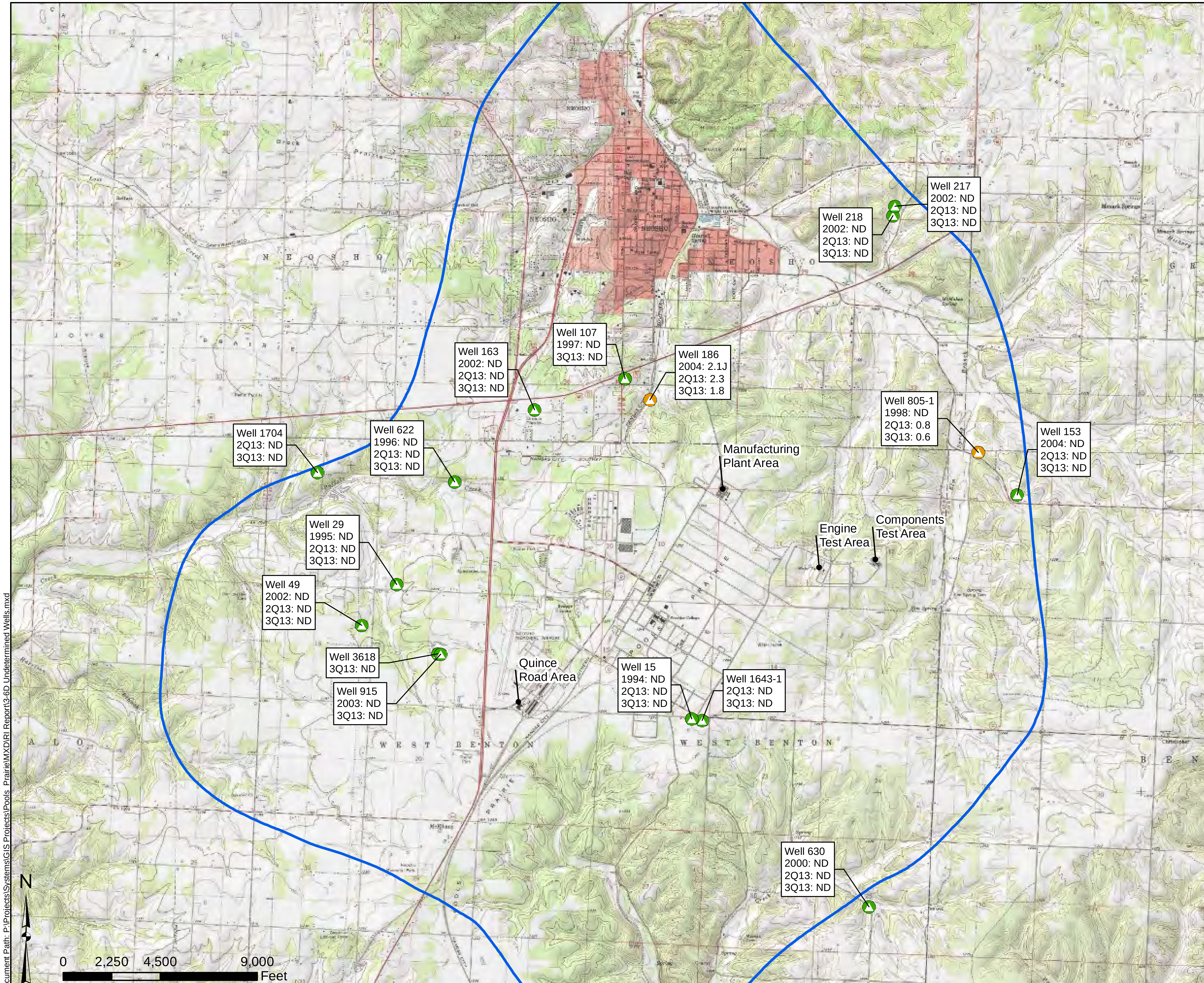
2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

TCE Results, Springfield Plateau Aquifer, Phase 1 RI

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 3-6C

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\3-5C Springfield Wells TCE.mxd



Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\3-6D Undetermined Wells.mxd

Aquifer Undetermined

Max TCE Detected, Phase 1 RI Sampling

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Phase 1 RI Study Area

Notes:

1. ND = Not Detected Above Detection Limit
2. J = Lab Estimated Value
3. All Concentration in Micrograms per Liter (µg/L)

Well 012345	Well ID
2002: 0.7	2002: Most Recent Result Prior to Ph 1
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

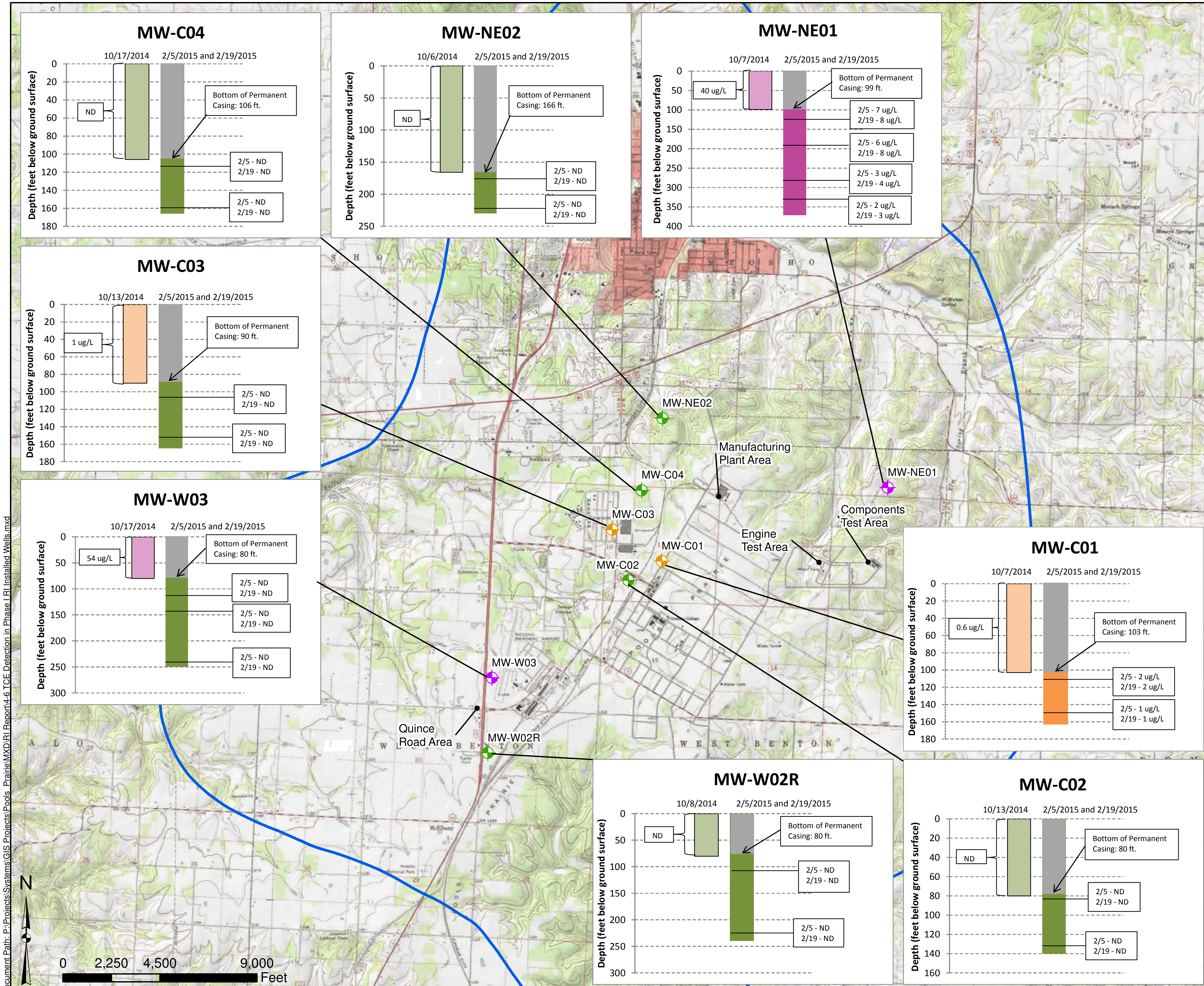
Pools Prairie Superfund Site
Newton County, Missouri

PROJECT NO.
60419811

TCE Results, Aquifer Undetermined, Phase 1 RI

DRN. BY: IJP
CHKD. BY: HB
2/16/2016

FIG. NO.
3-6D

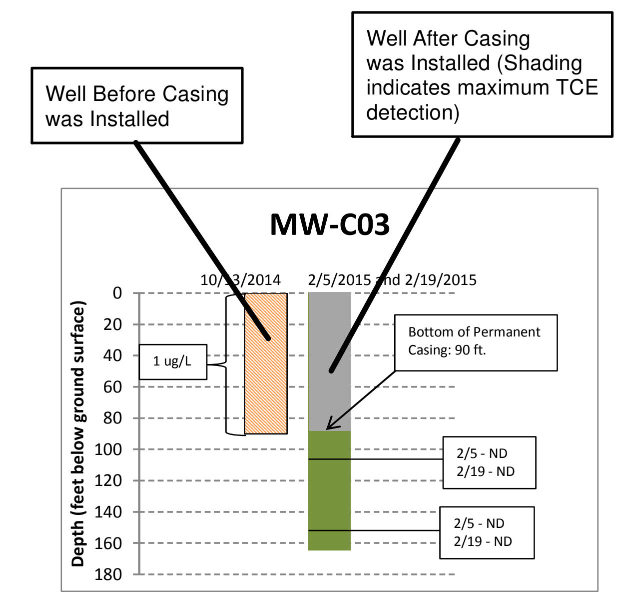


Wells Installed During Phase 1 RI

Max TCE Detected

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Phase 1 RI Study Area

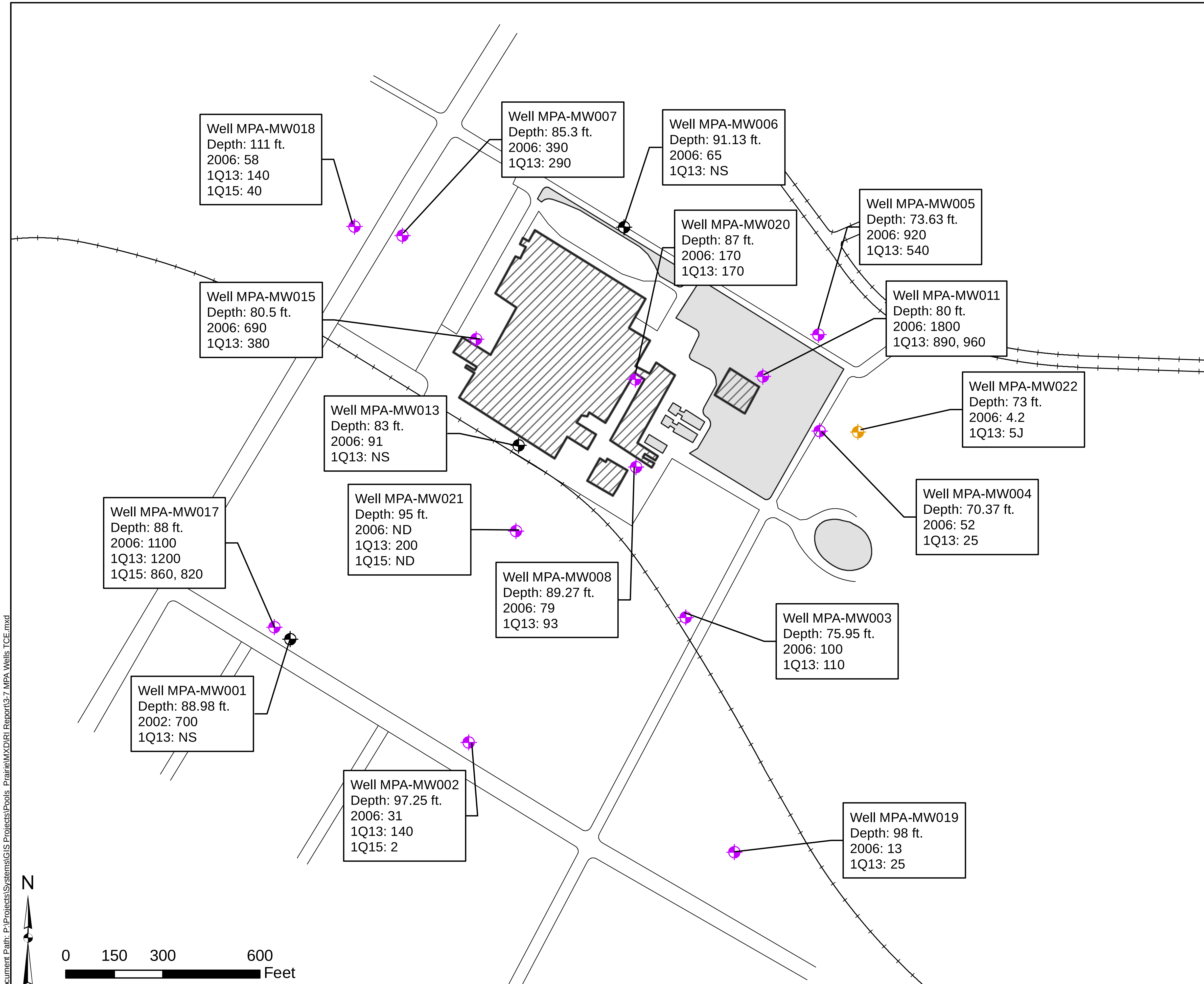
Wells were drilled in late 2014. An analytical sample was taken from each well from the uncased zone prior to completion of drilling and installation of permanent casing. Subsequently, after permanent casing was installed and the well was advanced to full depth, each well was sampled at various depths using diffusion bags. These sampling depths are reflected in the annotations for each well.



Data Source:
1. Phase 1 RI sampling on new wells was conducted between 2014 and 2015 by URS/AECOM.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
TCE Detections in Wells Installed During Phase 1 RI	
DRN. BY: IJP CHKD. BY: HB 8/28/2015	FIG. NO. 3-7

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed



MPA Wells

Max TCE Detected, Phase I RI Sampling

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Not Sampled during Phase 1 RI
- Building
- Pavement

Notes:

1. ND = Not Detected above Detection Limit
2. NS = Not Sampled
3. J = Lab Estimated Value
4. All Concentrations in Micrograms per Liter (µg/L)

Well 012345	Well ID
2002: 0.7	2002: Most Recent Result Prior to Ph 1
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

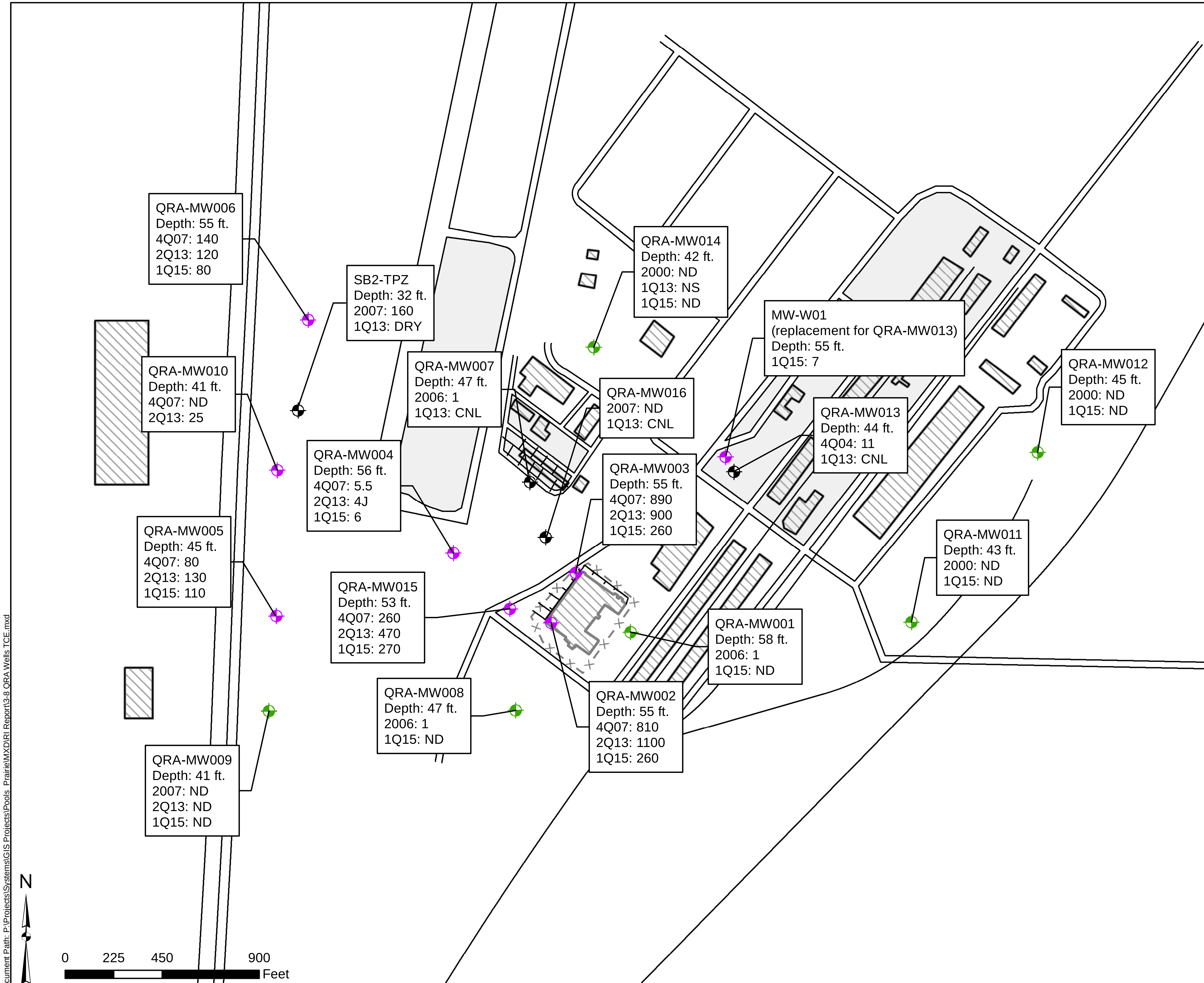
Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

TCE Detections in Monitoring Wells,
Manufacturing Plant Area (MPA)

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 3-8



Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\3-8 QRA Wells TCE.mxd

QRA Wells

Max TCE Detected, Phase 1 RI Sampling

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Not Sampled during Phase 1 RI
- Building
- Fence
- Pavement

Notes:

1. ND = Not Detected Above Detection Limit
2. NS = Not Sampled
3. CNL = Could Not Locate
4. J = Lab Estimated Value
5. All Concentrations in Micrograms per Liter (µg/L)

Well 012345	Well ID
2002: 0.7	2002: Most Recent Result Prior to Ph 1
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site
Newton County, Missouri

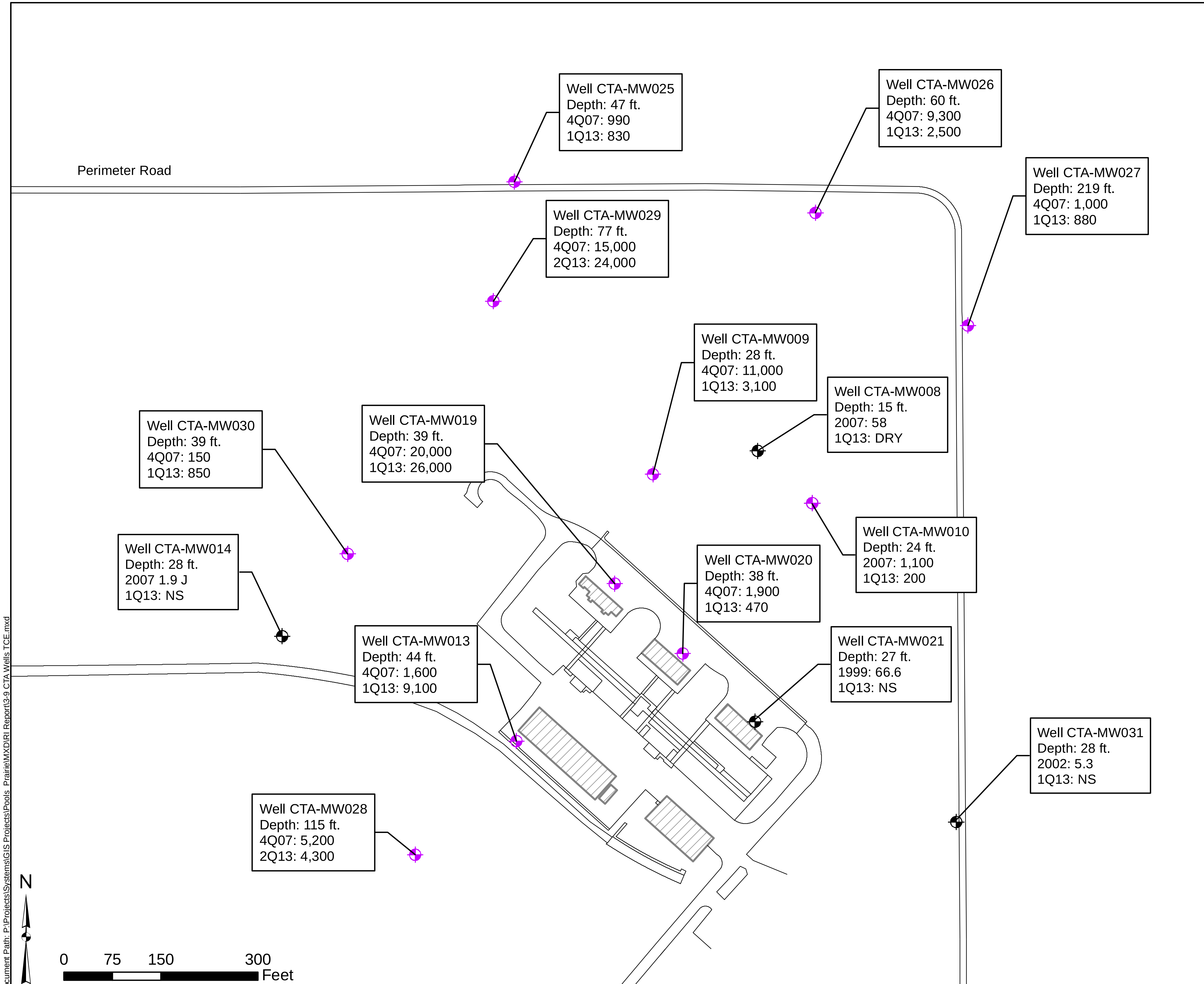
PROJECT NO.
60419811

TCE Detections in Monitoring Wells,
Quince Road Area (QRA)

DRN. BY: IJP
CHKD. BY: HB
12/1/2015

AECOM

FIG. NO.
3-9



CTA Wells

Max TCE Detected, Phase 1 RI Sampling

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Not Sampled During Phase 1 RI
- Building

Notes:

1. ND = Not Detected Above Detection Limit
2. NS = Not Sampled
3. J = Lab Estimated Value
4. All Concentrations in Micrograms per Liter (µg/L)

Well 012345	Well ID
2002: 0.7	2002: Most Recent Result Prior to Ph 1
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site
Newton County, Missouri

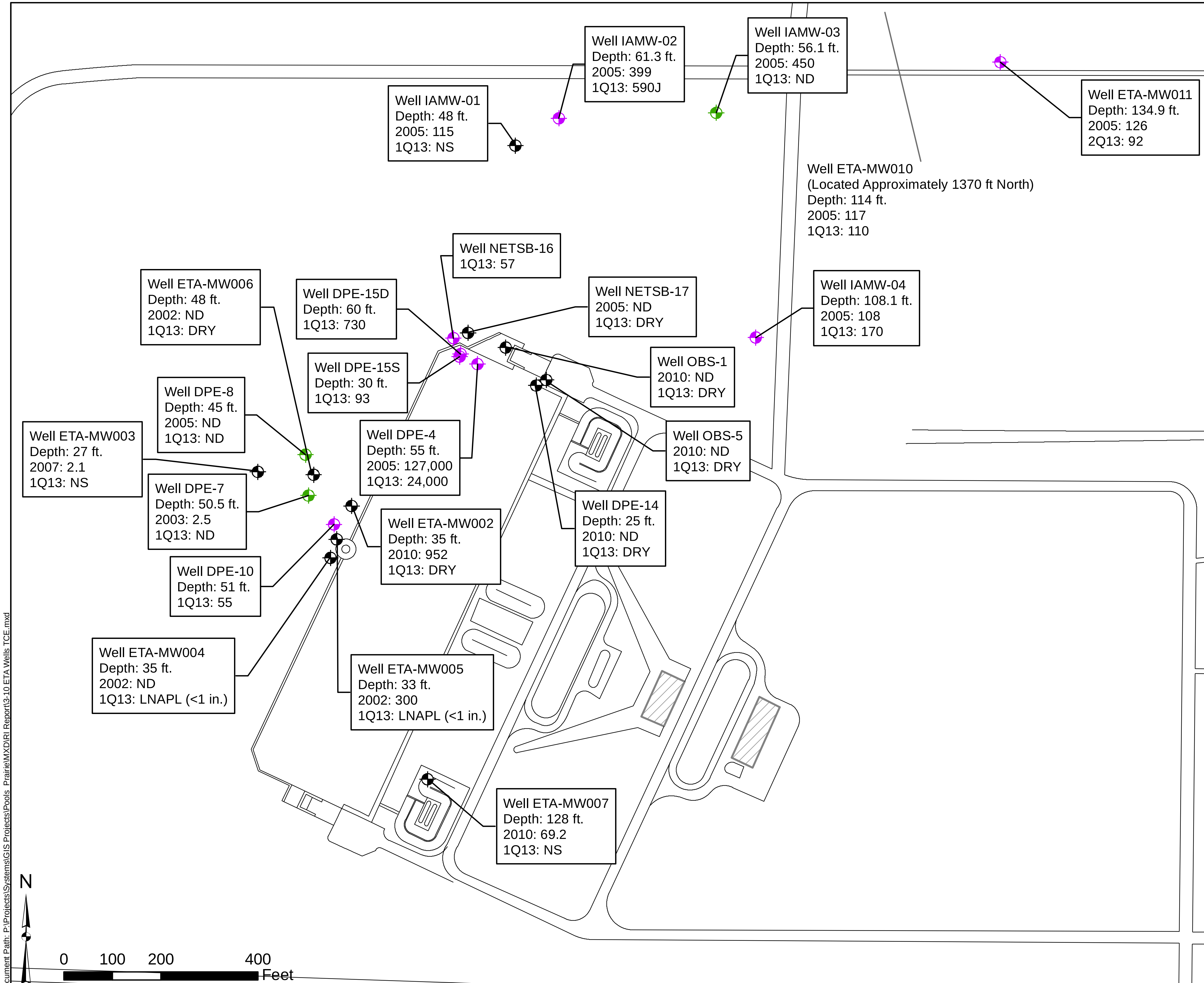
PROJECT NO.
60419811

TCE Detections in Monitoring Wells, Components Testing Area (CTA)

DRN. BY: IJP
CHKD. BY: HB
12/1/2015

AECOM

FIG. NO.
3-10



Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\3-10 ETA Wells TCE.mxd

ETA Wells

Max TCE Detected, Phase 1 RI Sampling

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Not Sampled During Phase 1 RI
- Building

Notes:

1. ND = Not Detected Above Detection Limit
2. NS = Not Sampled
3. LNAPL = Light Non-Aqueous Phase Liquid with Thickness in Parentheses
4. J = Lab Estimated Value
5. All Concentrations in Micrograms per Liter (µg/L)

Well 012345	Well ID
2002: 0.7	2002: Most Recent Result Prior to Ph 1
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site
Newton County, Missouri

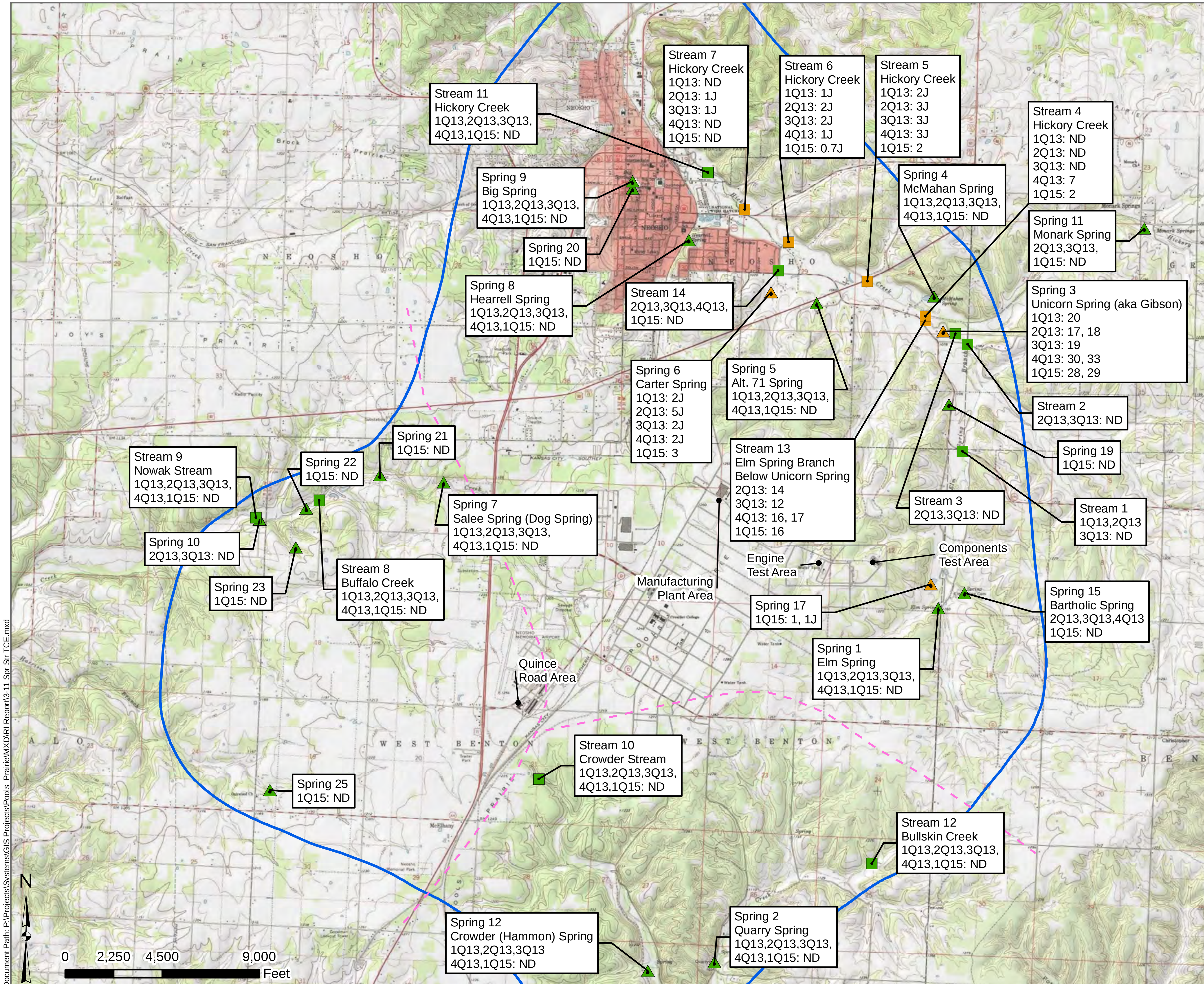
PROJECT NO.
60419811

TCE Detections in Monitoring Wells, Engine Testing Area (ETA)

DRN. BY: IJP
CHKD. BY: HB
12/1/2015

AECOM

FIG. NO.
3-11



Sampled Streams

TCE Detections, Phase 1 RI Sampling

- No TCE Detected Above Detection Limit
- TCE Detected

Sampled Springs

TCE Detections, Phase 1 RI Sampling

- No TCE Detected Above Detection Limit
- TCE Detected
- Inferred Recharge Area
- Phase 1 RI Study Area

Notes:

1. ND = Not Detected above Detection Limit
2. J = Lab Estimated Value
3. All Concentrations in Micrograms per Liter (µg/L)

Spring 012345	Spring/Stream ID
Unnamed Spring	Spring/Stream Name
2Q13: 0.5	2nd Quarter 2013: Sample Result
3Q13: ND	3rd Quarter 2013: Not Detected
4Q14: 0.7, 0.8	4th Quarter 2014: Multiple Samples this Quarter

Data Source:
1. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site
Newton County, Missouri

PROJECT NO. 60419811

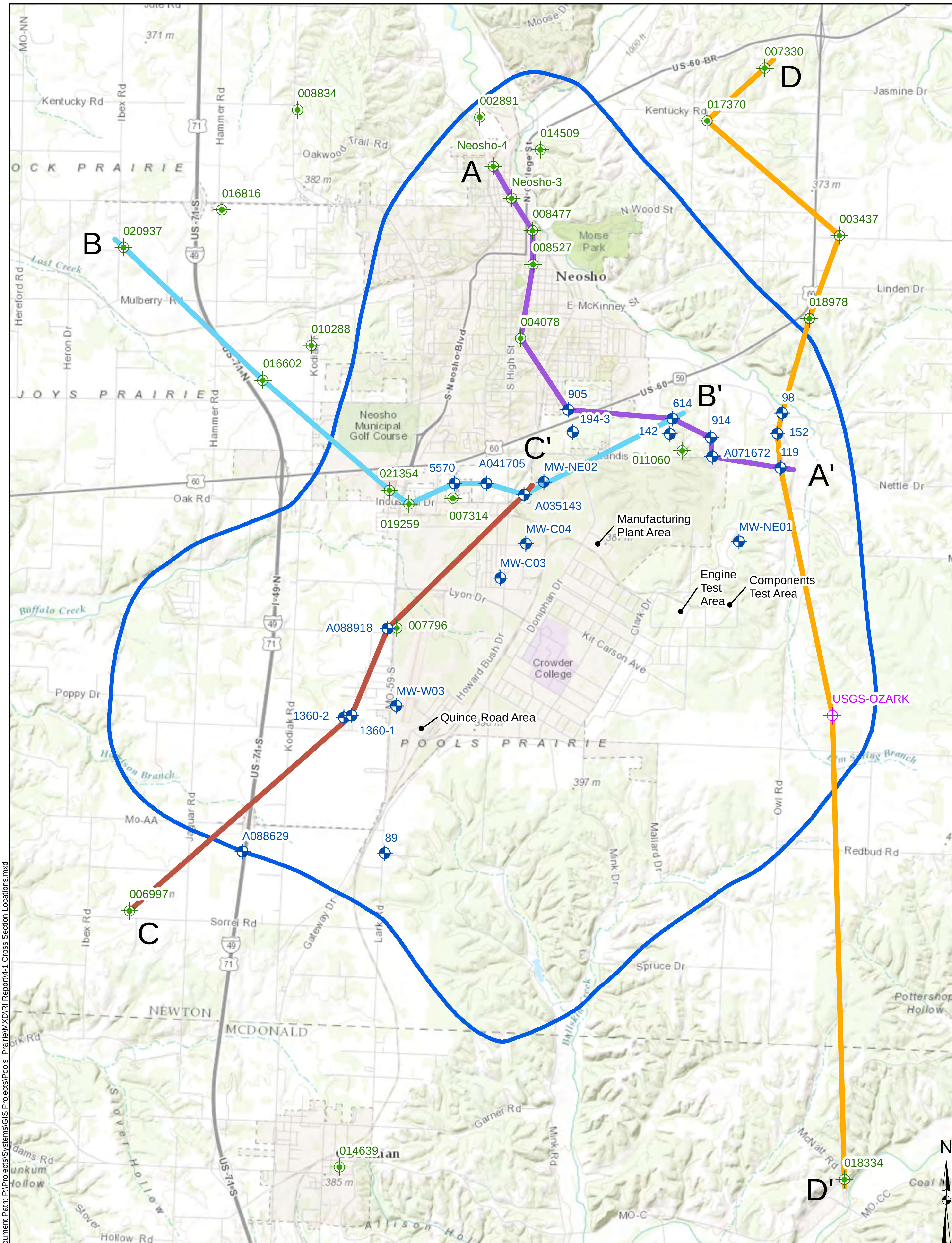
TCE Detections in Sampled Springs and Streams

DRN. BY: IJP
CHKD. BY: HB
11/10/2015

AECOM

FIG. NO. 3-12

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\3-11 Spr Str TCE.mxd



Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\4-1 Cross Section Locations.mxd

Cross Section Wells

Data Source

- MDNR Drilling Log
- Phase 1 RI Optical Borehole Image (OBI)
- USGS Drilling Log

Cross Section Axes

Cross Section Name

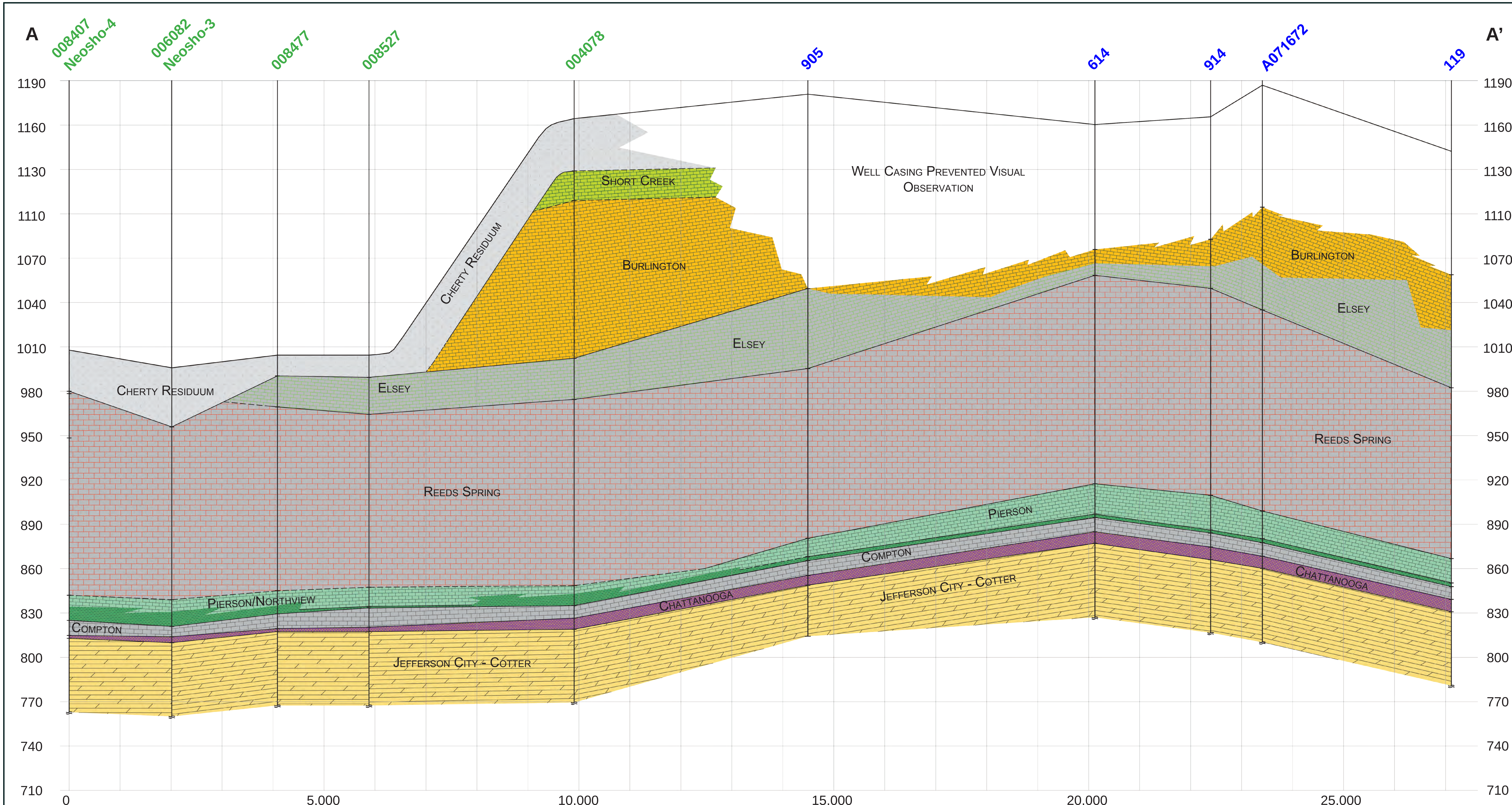
- A-A'
- B-B'
- C-C'
- D-D'

Phase 1 RI Study Area

0 2,500 5,000 10,000 Feet

Data Source:
1. Well locations were determined through examination of boring logs and URS/AECOM field work.
Cross Sections were chosen based on availability of data.

Pools Prairie Superfund Site Newton County, Missouri		PROJECT NO. 60419811
Cross Section Location Map		
DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 4-1



Legend:

Springfield Plateau Aquifer
- Warsaw - LS
- Short Creek - LS
- Burlington - Keokuk - LS
- Elsey - LS
- Reeds Spring - LS

May Be Part of OCU
- Pierson - LS

Ozark Confining Unit
- Northview - SH
- Compton - LS
- Chattanooga - SH

Ozark Aquifer
- Jefferson City - Cotter - DO

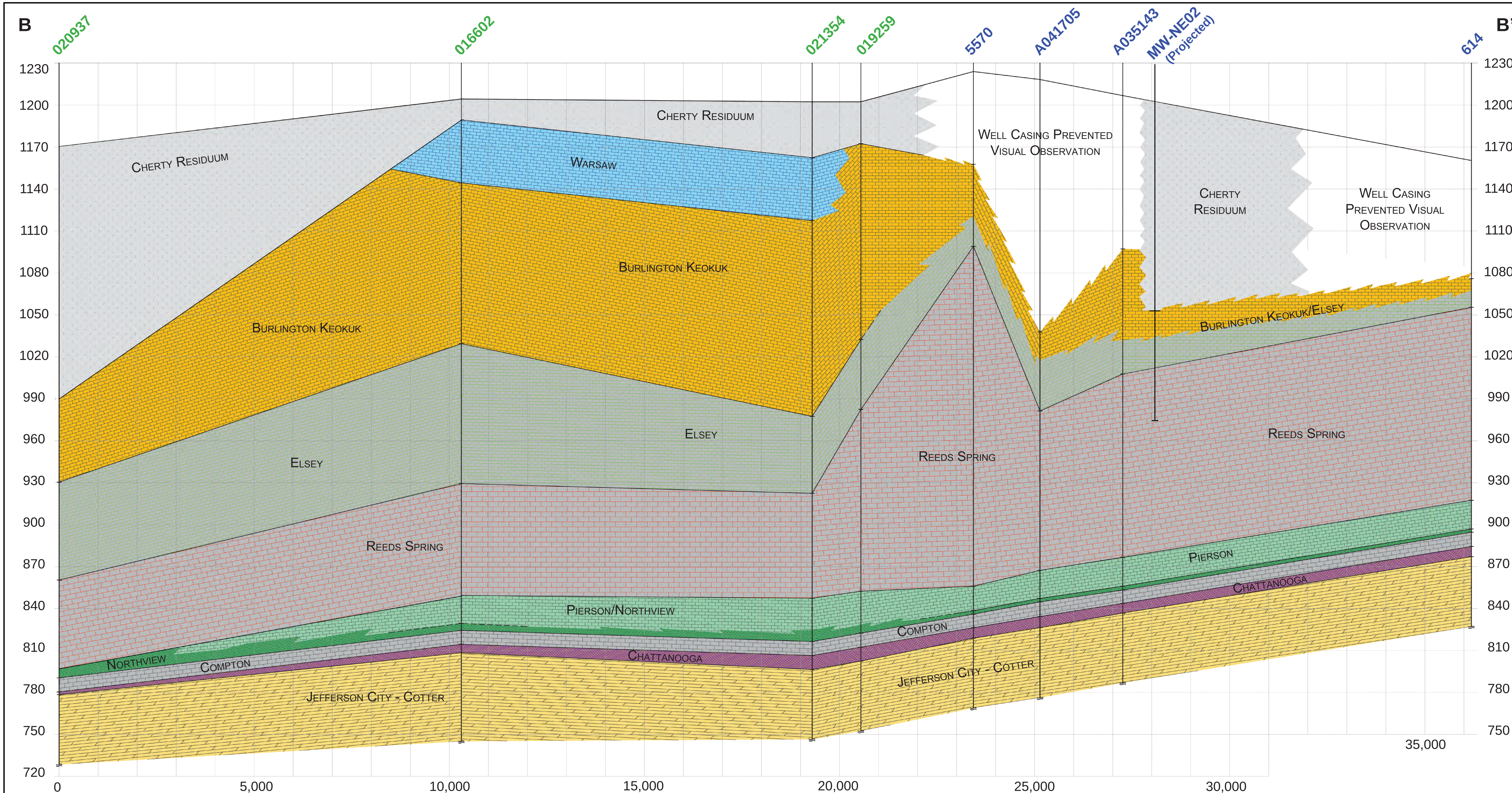
- Cherty Residuum
- No Information Due to Well Casing

614 Phase 1 RI Downhole Camera Location

004078 MDNR Logged Well Location

Notes:
1. Many of the MDNR boring logs show the Fern Glen LS at the sequence location that the Pierson LS is located at, therefore, the strata described as Fern Glen on MDNR logs has been interpreted as Pierson LS on this cross section.
2. Many of the MDNR boring logs show the Grand Falls LS at the sequence location that the Elsey is located at, therefore, the strata described as Grand Falls on MDNR logs has been interpreted as Elsey LS on this cross section.
3. The Short Creek is not a separate formation; it is the upper member of the Burlington-Keokuk and is used as a marker between the Burlington-Keokuk and the Warsaw.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Geologic Cross Section A-A'	
DRN. BY: CTD CHKD. BY: RJE 7/24/15	AECOM
FIG. NO. 4-1A	



Legend:

Springfield Plateau Aquifer:
- Warsaw - LS
- Short Creek - LS
- Burlington - Keokuk - LS
- Elsey - LS
- Reeds Spring - LS

May Be Part of OCU:
- Pierson - LS

Ozark Confining Unit:
- Northview - SH
- Compton - LS
- Chattanooga - SH

Ozark Aquifer:
- Jefferson City - Cotter - DO

- Cherty Residuum
- No Information Due to Well Casing

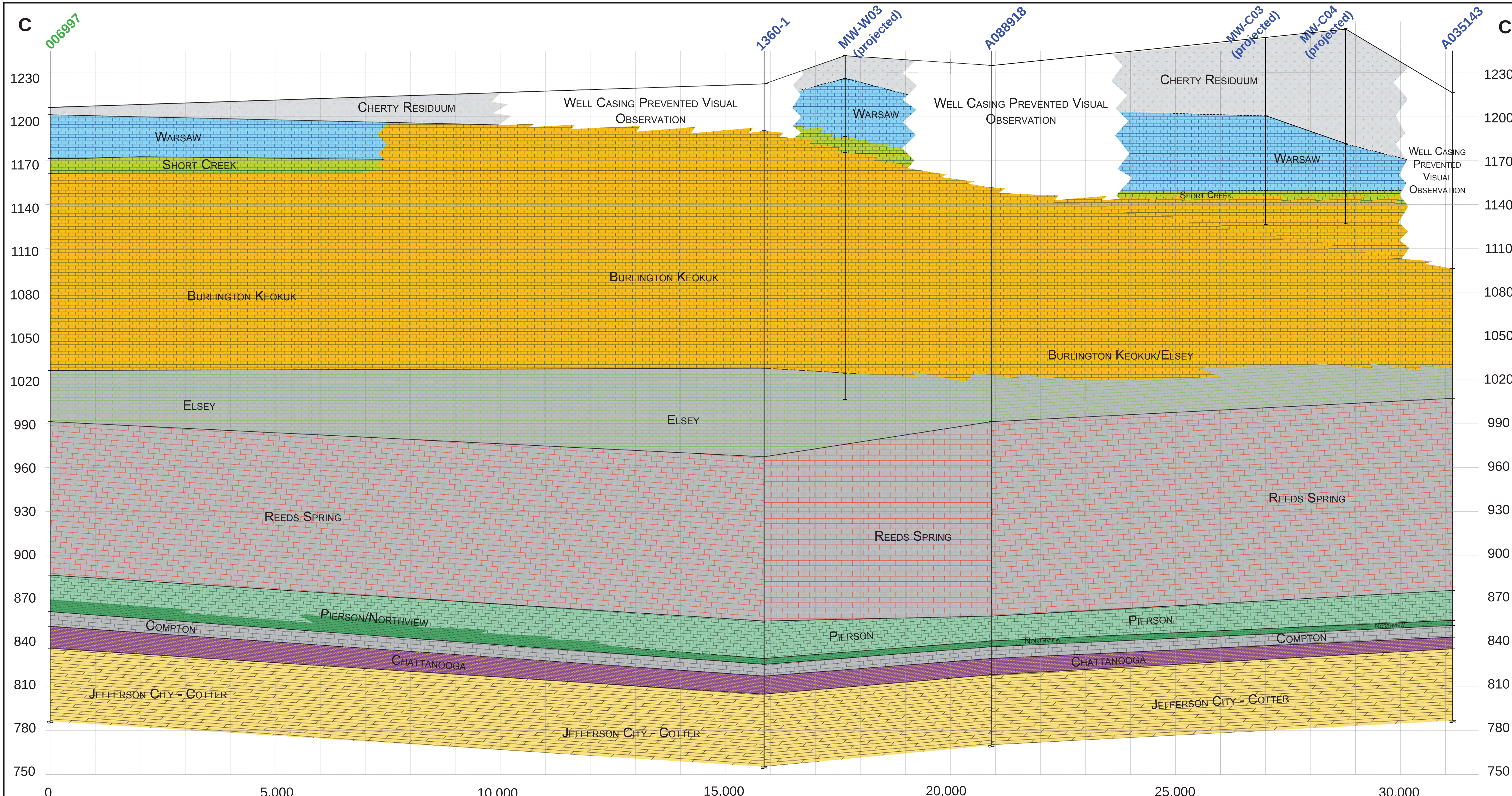
5570 Phase 1 RI Downhole Camera Location

16602 MDNR Logged Well Location

Notes:

1. Many of the MDNR boring logs show the Fern Glen LS at the sequence location of the Pierson LS, therefore, the strata described as Fern Glen on MDNR logs has been interpreted as Pierson LS on this cross section.
2. Many of the MDNR boring logs show the Grand Falls LS at the sequence location of the Elsey, therefore, the strata described as Grand Falls on MDNR logs has been interpreted as Elsey LS on this cross section.
3. The Short Creek is not a separate formation; it is the upper member of the Burlington-Keokuk and is used as a marker between the Burlington-Keokuk and the Warsaw.
4. Based on geologic mapping (Whitfield 1999), the Warsaw is present at 019259 and 5570; however, it is often indistinguishable from the Burlington-Keokuk.
5. The apparent lithology change at Well 5570 appears to be the result of different interpretations of formation boundaries. All the formations above the Pierson are cherty limestones.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Geologic Cross Section B-B'	
DRN. BY: HRB CHKD. BY: MCH 9/24/15	AECOM — FIG. NO. 4-1B



Legend:

Springfield Plateau Aquifer
- Warsaw - LS
- Short Creek - LS
- Burlington - Keokuk - LS
- Elsey - LS
- Reeds Spring - LS

May Be Part of OCU
- Pierson - LS

Ozark Confining Unit
- Northview - SH
- Compton - LS
- Chattanooga - SH

Ozark Aquifer
- Jeffersoan City - Cotter - DO

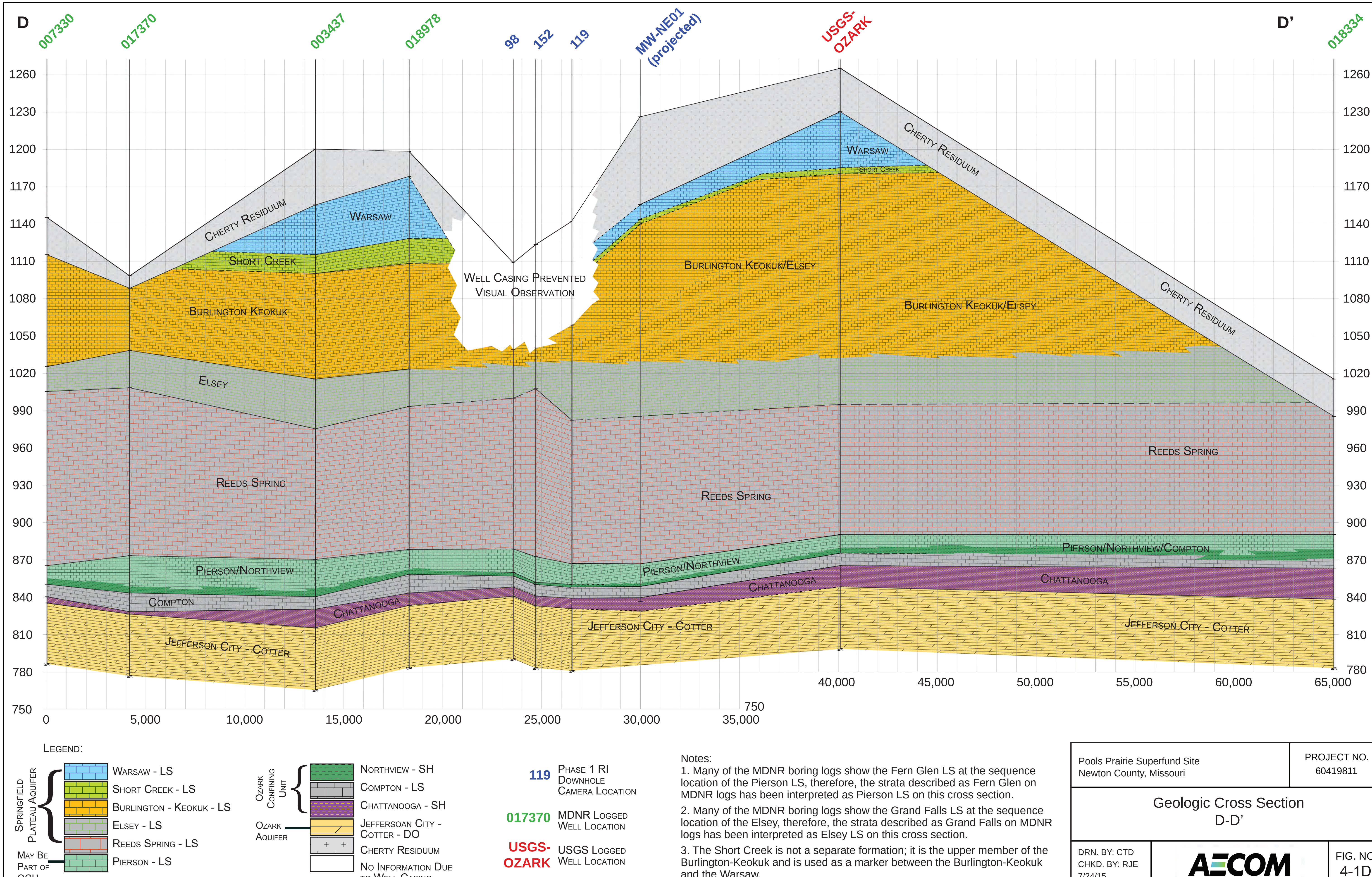
- Cherty Residuum
- No Information Due to Well Casing

1360-1 Phase 1 RI Downhole Camera Location

006997 MDNR Logged Well Location

Notes:
1. Many of the MDNR boring logs show the Fern Glen LS at the sequence location of the Pierson LS, therefore, the strata described as Fern Glen on MDNR logs has been interpreted as Pierson LS on this cross section.
2. Many of the MDNR boring logs show the Grand Falls LS at the sequence location of the Elsey, therefore, the strata described as Grand Falls on MDNR logs has been interpreted as Elsey LS on this cross section.
3. The Short Creek is not a separate formation; it is the upper member of the Burlington-Keokuk and is used as a marker between the Burlington-Keokuk and the Warsaw.

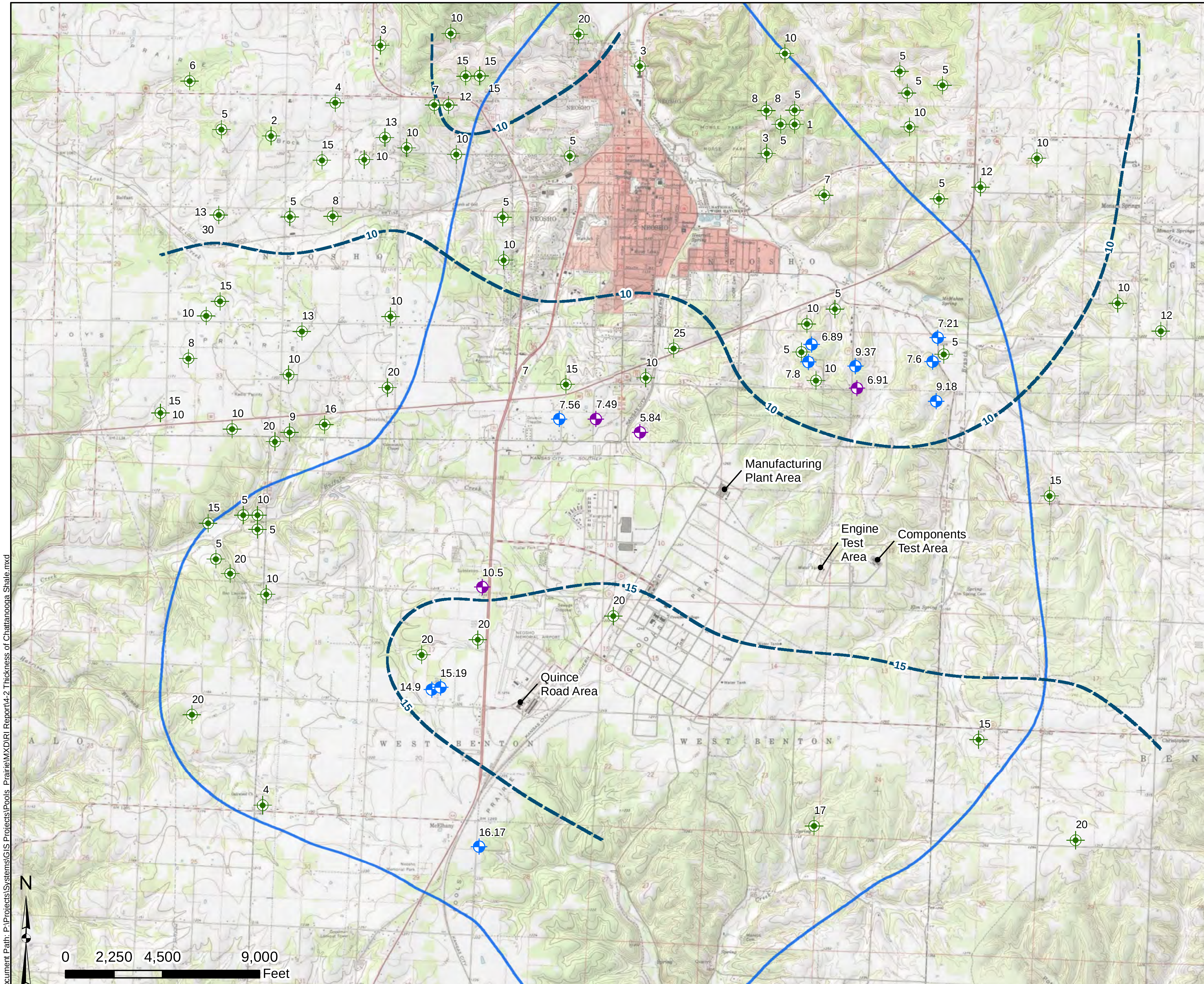
Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Geologic Cross Section C-C'	
DRN. BY: CTD CHKD. BY: RJE 7/24/15	FIG. NO. 4-1C



Notes:

1. Many of the MDNR boring logs show the Fern Glen LS at the sequence location of the Pierson LS, therefore, the strata described as Fern Glen on MDNR logs has been interpreted as Pierson LS on this cross section.
2. Many of the MDNR boring logs show the Grand Falls LS at the sequence location of the Elsey, therefore, the strata described as Grand Falls on MDNR logs has been interpreted as Elsey LS on this cross section.
3. The Short Creek is not a separate formation; it is the upper member of the Burlington-Keokuk and is used as a marker between the Burlington-Keokuk and the Warsaw.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Geologic Cross Section D-D'	
DRN. BY: CTD CHKD. BY: RJE 7/24/15	FIG. NO. 4-1D



- MDNR Drilling Log (thickness in ft)
- Phase 1 RI OBI (thickness in ft)
- Phase 1 RI OBI/MDNR Drilling Log (thickness in ft)
- Chattanooga Shale thickness (ft)
- Phase 1 RI Study Area

Notes:
1. Statistical method of kriging used to generalize unit thickness, some point anomolies fall outside general contour interval.

2. The thinnest instance of the Chattanooga Shale recorded was one foot, found in the MDNR boring log for well A050340.

3. The thinnest instance of the Chattanooga Shale observed during Phase 1 RI field work was 5.84 feet, observed at well A035143 with an OBI (optical borehole imagery).

Data Source:
1. Missouri Department of Natural Resources Missouri Geological Survey, Geological data collected from well logs as early as 1869 has been accumulated in various formats. Publication Date:20061015, Title:WELL_LOGS

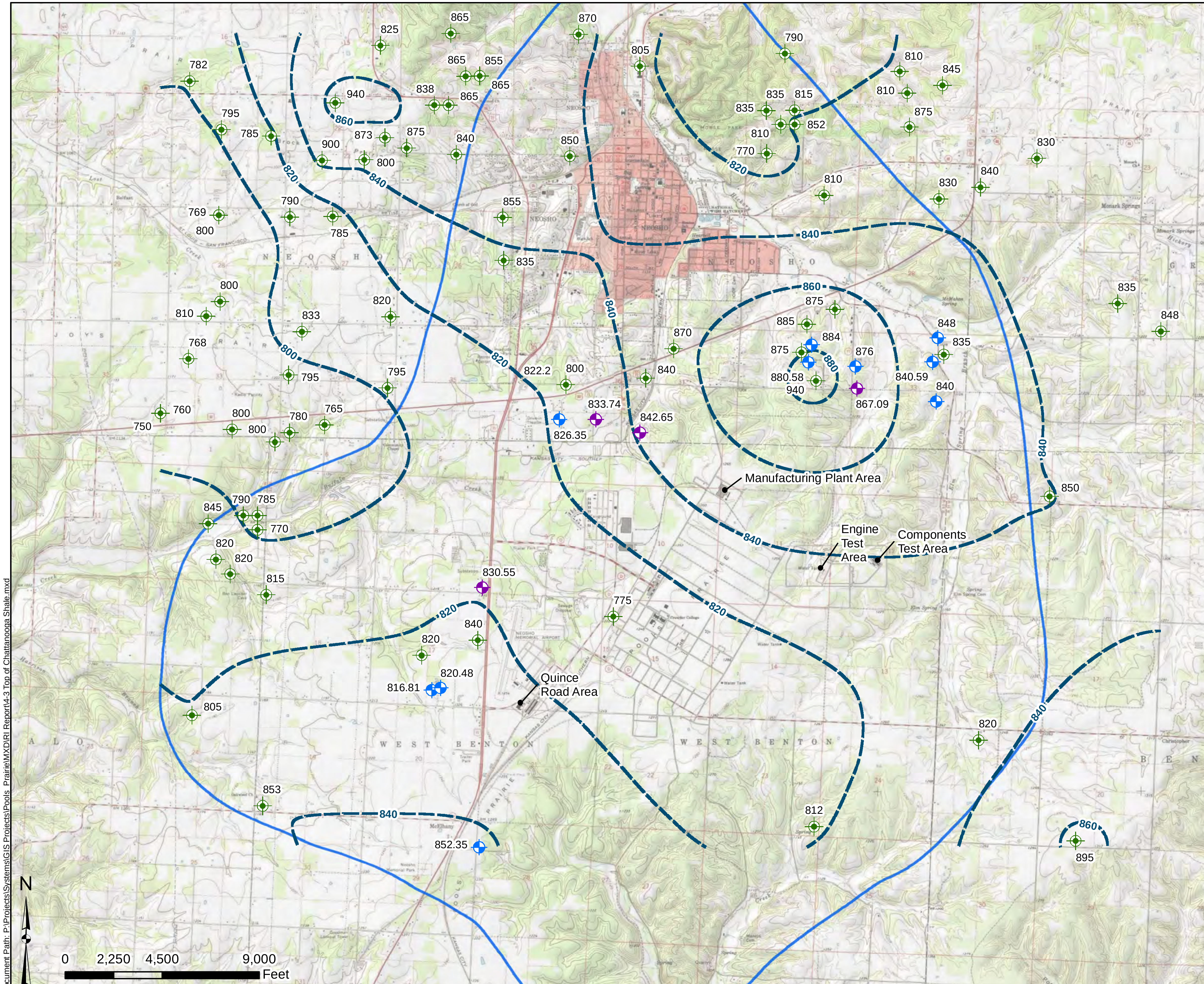
2. OBIs (optical borehole images) collected by URS/AECOM were used to identify the thickness of the Chattanooga Shale.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Thickness of Chattanooga Shale

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 4-2

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\4-2 Thickness of Chattanooga Shale.mxd



MDNR Drilling Log
Phase 1 RI OBI
Phase 1 RI OBI/MDNR Drilling Log
Top of Chattanooga Shale Contour (ft amsl)
Phase 1 RI Study Area

Notes:
1. Elevations associated with each data point shown are in ft above mean sea level (amsl).

Data Source:
1. Missouri Department of Natural Resources Missouri Geological Survey, Geological data collected from well logs as early as 1869 has been accumulated in various formats. Publication Date:20061015, Title:WELL_LOGS

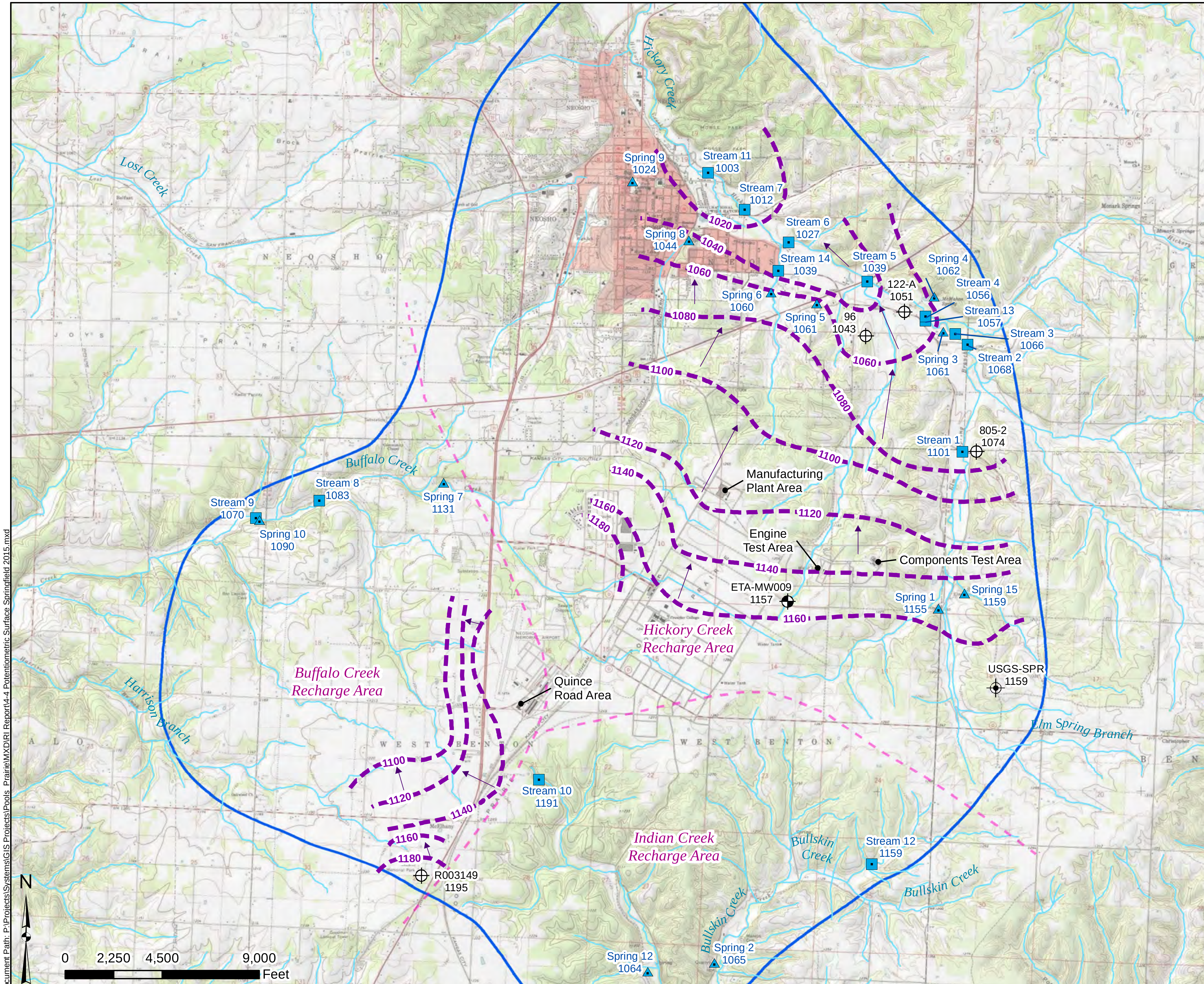
2. OBIs (optical borehole images) collected by URS/AECOM were used to identify the location of the Chattanooga Shale.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Elevation of Top of Chattanooga Shale

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 4-3

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\4-3 Top of Chattanooga Shale.mxd



- Spring
- Stream
- Other Well
- Monitoring Well
- Private Well
- Groundwater Surface Elevation (ft amsl)
- Inferred Recharge Area
- Phase 1 RI Study Area

Notes:

1. Only wells greater than approximately 130 ft in depth were used to develop the contours as shallower wells are affected by perched water conditions.

2. Note that the potentiometric surface intersects some perennial water features but not others.

3. Groundwater elevations are shown in feet above mean sea level.

Data Source:

1. Groundwater level measurements were collected from January 19 through January 22, 2015 by URS/AECOM.

2. Results from December 2014 packer tests for wells 1360-2 and A035143 are included.

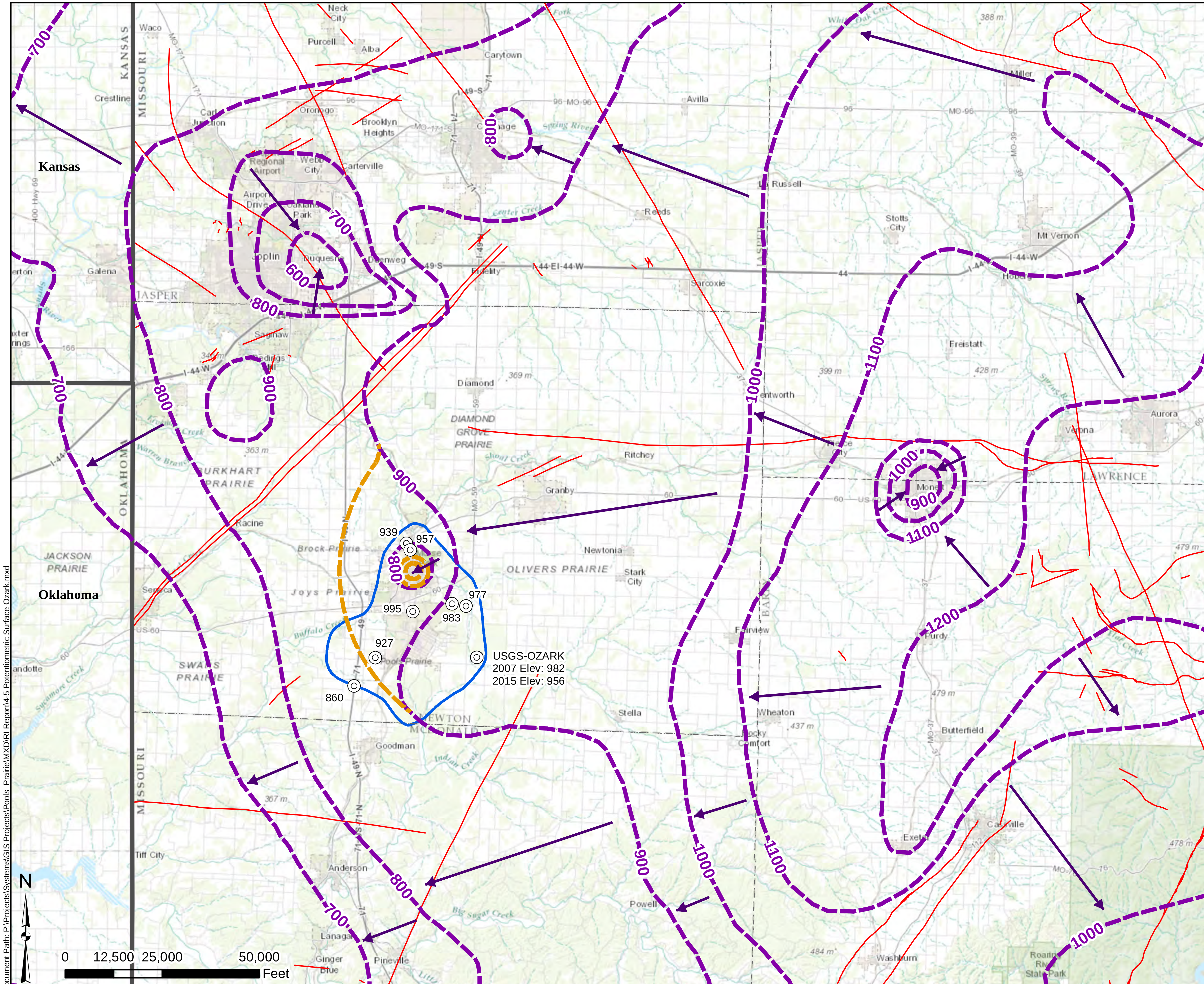
3. Groundwater data for USGS-SPR was obtained from "http://nwis.waterdata.usgs.gov". The average groundwater elevation from January 19 through January 22, 2015 was used. During this time period groundwater elevations ranged from 1158.50 feet to 1158.78 feet.

4. Well elevations were gathered from appropriate well surveys.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

2015 Groundwater Potentiometric Surface, Springfield Plateau Aquifer

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 4-4



Ozark Aquifer Well (Measured Elevation of Ozark Water Level in Well, ft above mean sea level)

Potentiometric Surface Adjusted for 2014-2015 Pools Prairie Data

Composite 2006-2007 Potentiometric Surface

State Boundaries

County Boundaries

Geologic Structures

Phase 1 RI Study Area

Data Source:
1. Figure 5. Composite 2006-2007 Potentiometric map of southwestern Missouri (data source: USGS Scientific Investigations Report 2007-5253, USGS Scientific Investigations Map 3003, and U.S. Army Corps of Engineers Planning Assistance to States project [in press]). Contour lines show potentiometric surface elevation in feet above mean sea level.

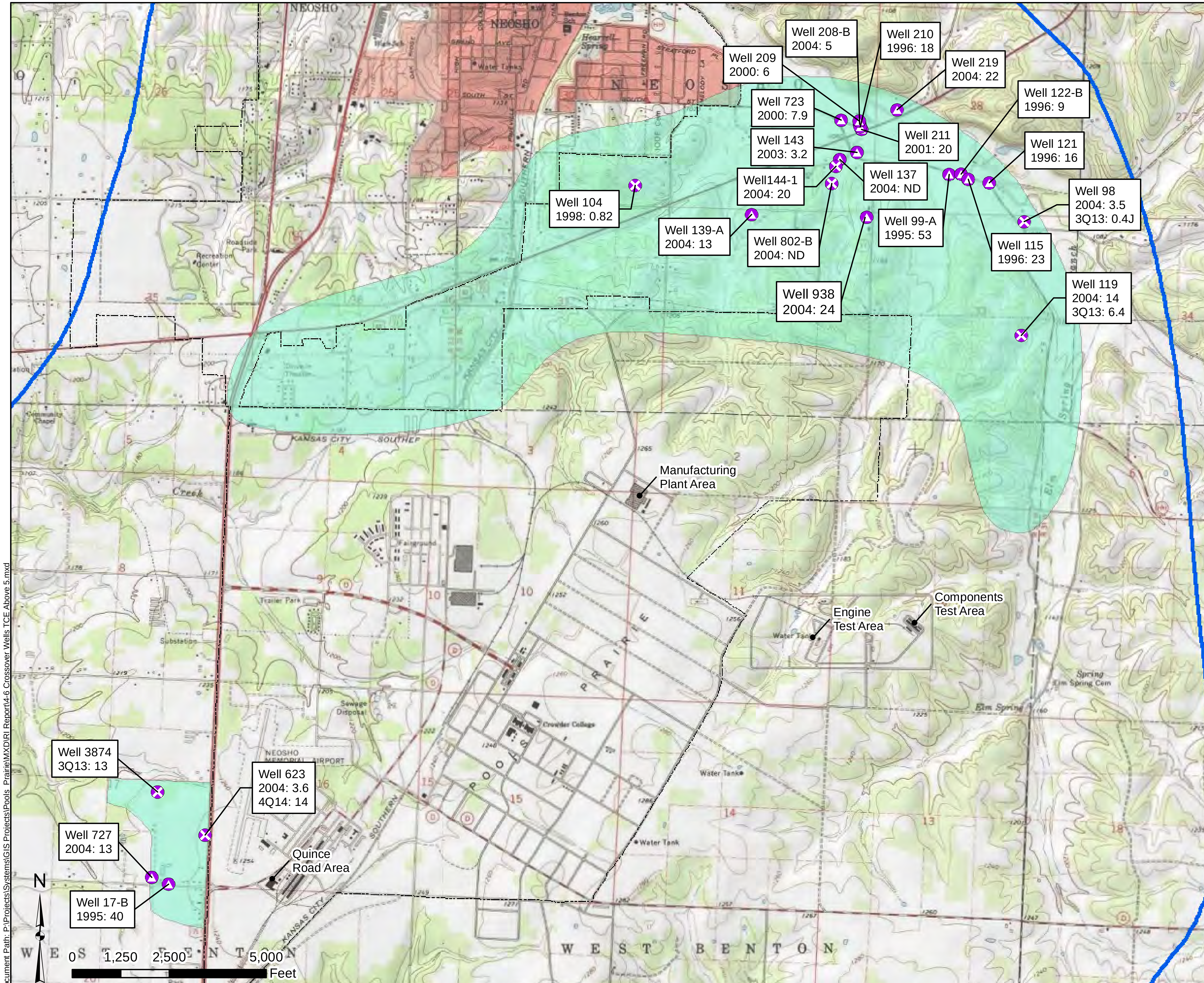
2. Groundwater elevations shown were measured in non-pumped wells. Measurements are either from wells cased through the Ozark Confining Unit, or from crossover wells in which the Ozark pressure head was measured while isolating the Ozark using a packer in the Ozark Confining Unit.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Composite Potentiometric Surface, Ozark Aquifer

DRN. BY: IJP CHKD. BY: HB 11/18/2015	AECOM	FIG. NO. 4-5

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\4-5 Potentiometric Surface Ozark.mxd



Crossover Wells

(wells open to both the SPA and Ozark Aquifers)

Historical Maximum TCE >5 µg/L

Undetermined Aquifer (Potential Crossover) Wells

Historical Maximum TCE >5 µg/L

Phase 1 RI Study Area

Neosho City Limits

Areas Offered City Water

Notes:

1. All Concentrations in Micrograms per Liter (µg/L).

2. Figure includes both Phase 1 RI sampled and historically sampled wells that have had at least one TCE detection above 5 µg/L.

3. Annotations show most recent TCE detection prior to Phase 1 as well as results from Phase 1 RI sampling.

Well 012345 2002: 10 2Q13: 7	Well ID 2002: Most Recent Result Prior to Ph 1 2nd Quarter 2013: Max Result from Phase 1 Sampling

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site
Newton County, Missouri

PROJECT NO.
60419811

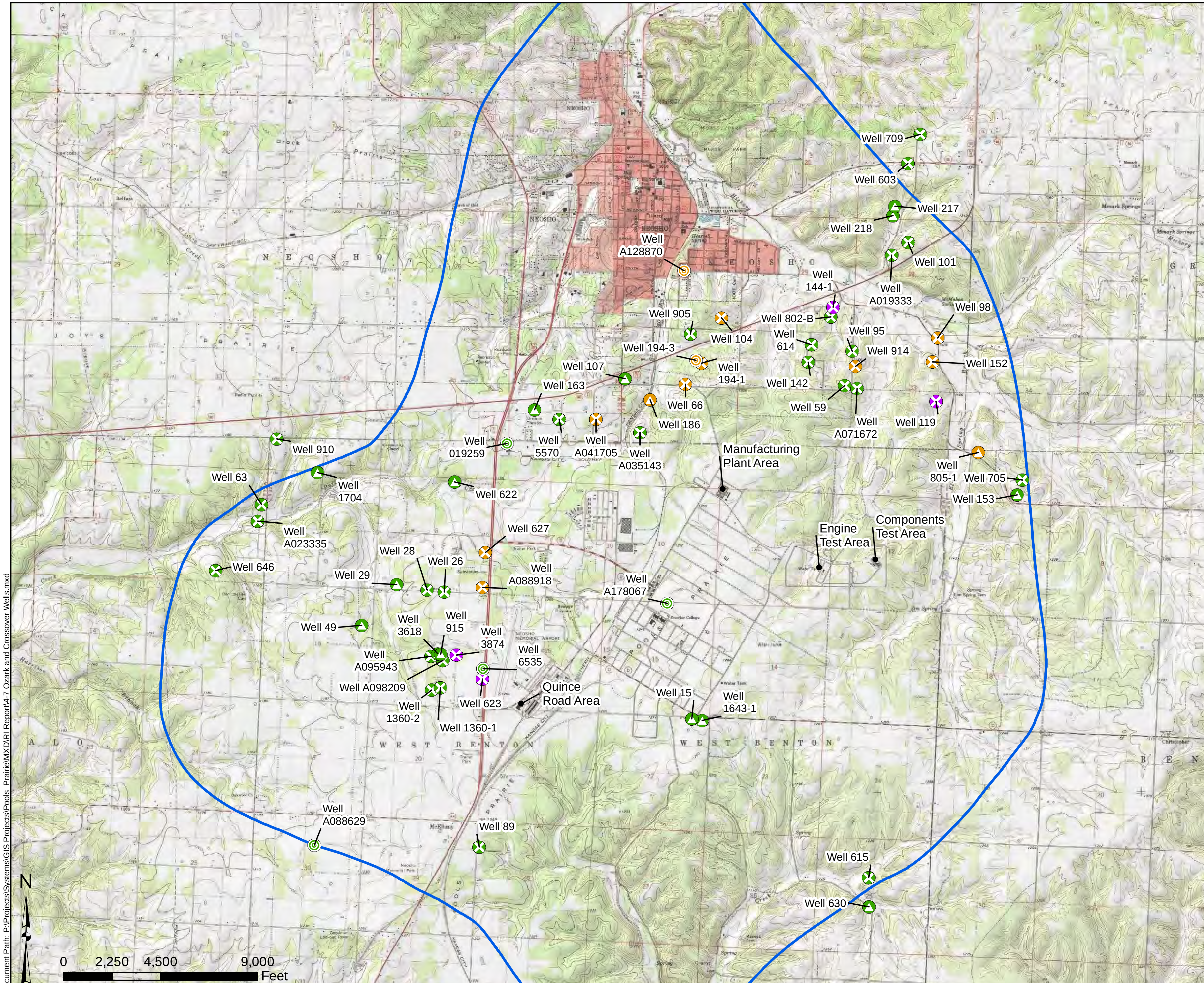
Crossover Wells or Potential Crossover Wells with Historical TCE Detections above 5 µg/L

DRN. BY: IJP
CHKD. BY: HB
2/16/2016

AECOM

FIG. NO.
4-6

Document Path: P:\Projects\Systems\GIS Projects\Pools Prairie\MXD\RI Report\4-6 Crossover Wells TCE Above 5.mxd



Phase 1 RI Sampled Undetermined Aquifer Wells

Max TCE Detected, Phase 1 RI

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L

Phase 1 RI Sampled Ozark Aquifer Wells

Max TCE Detected, Phase 1 RI

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L

Historical and Phase 1 RI Sampled Crossover Wells

Max TCE Detected, Phase 1 RI

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L

Phase 1 RI Study Area

Notes:

1. Crossover wells not sampled during Phase 1 RI are symbolized based upon their most recent TCE sample result prior to Phase 1.

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

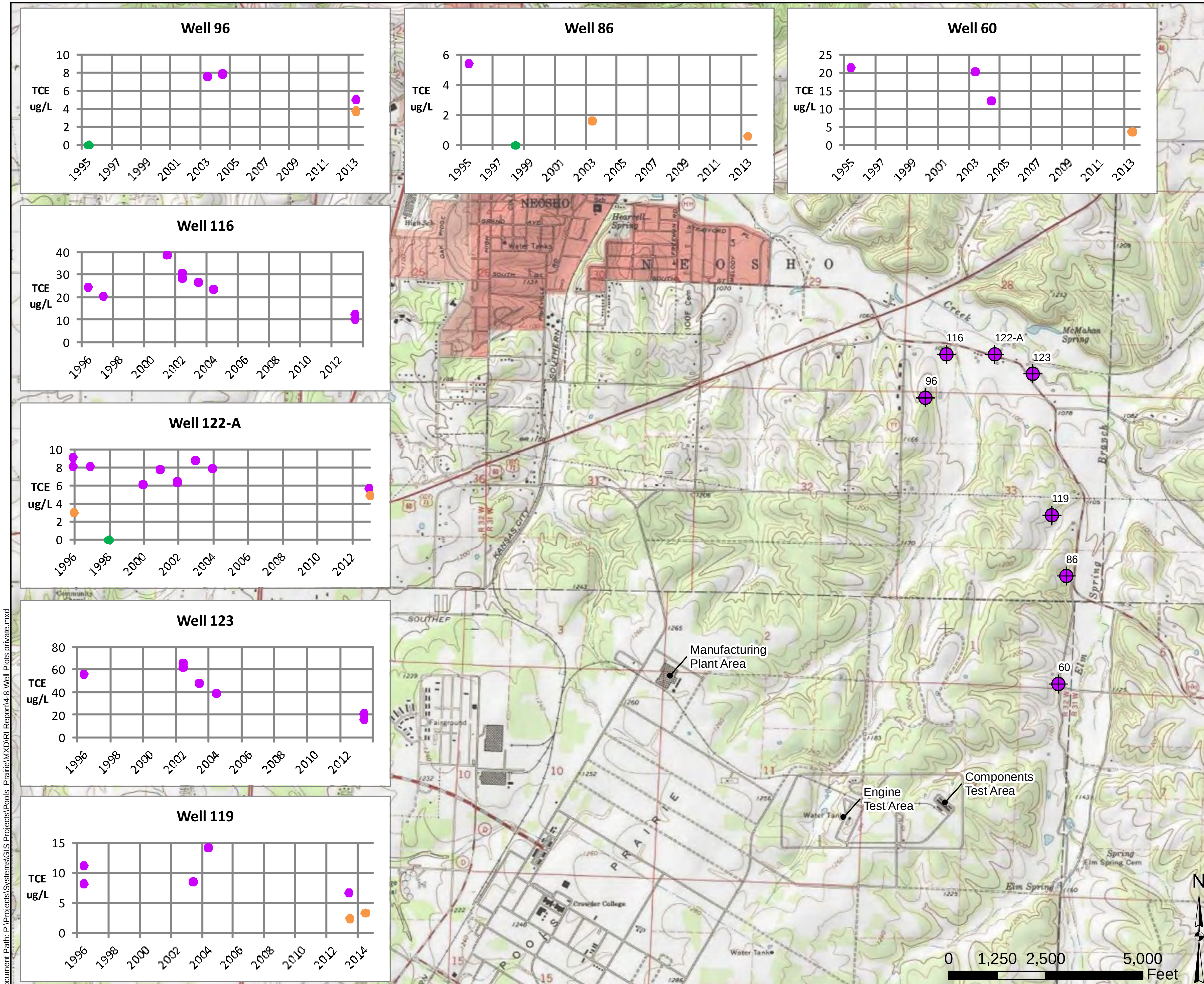
2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

TCE Detections in Sampled Crossover, Ozark, and Undetermined Aquifer Wells

DRN. BY: IJP CHKD. BY: HB 2/16/2016	AECOM	FIG. NO. 4-7

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\4-7 Ozark and Crossover Wells.mxd



Private Wells

Max TCE > 5 µg/L

Notes:

1.Wells were selected for inclusion in the figure by the following criteria:

a. Detected TCE concentrations above 5 µg/L.

b. Data available from both before and after 2004-2008, when removal actions were performed at the ETA and CTA.

2. Non Detects are represented on the plots as zeroes.

Data Source:

1. TCE results prior to 2013 were provided by others. See Appendix B for details.

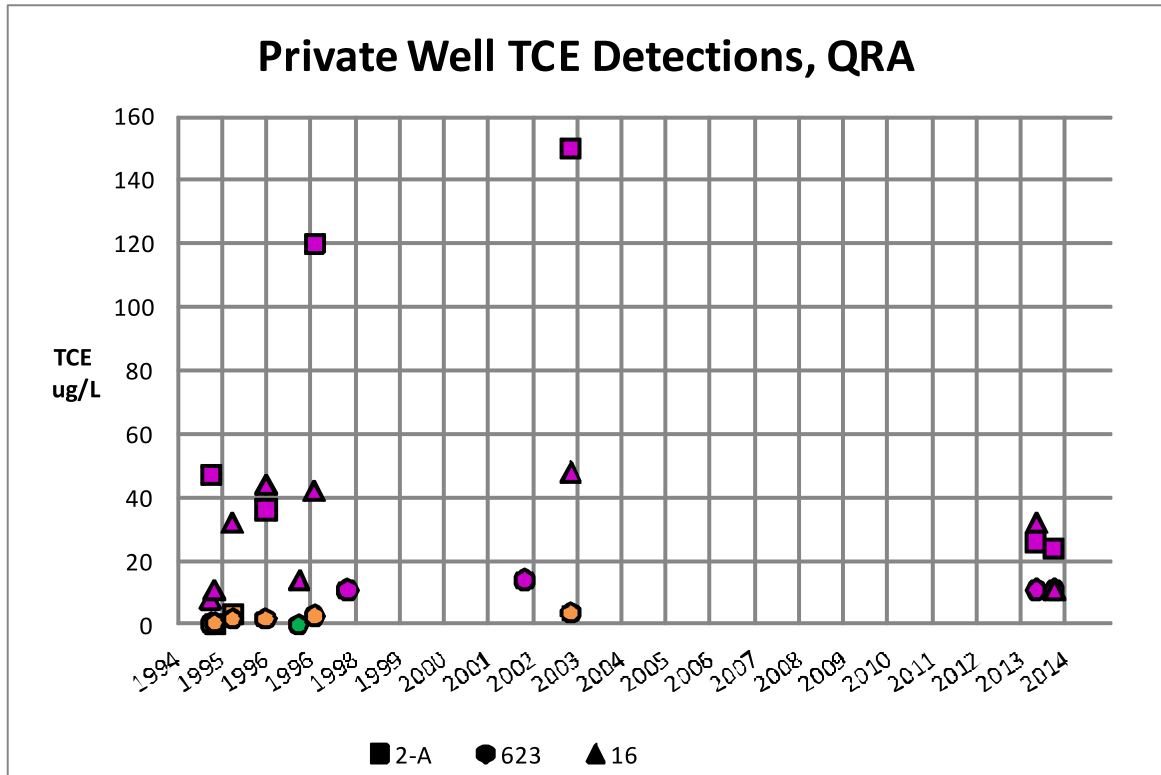
2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

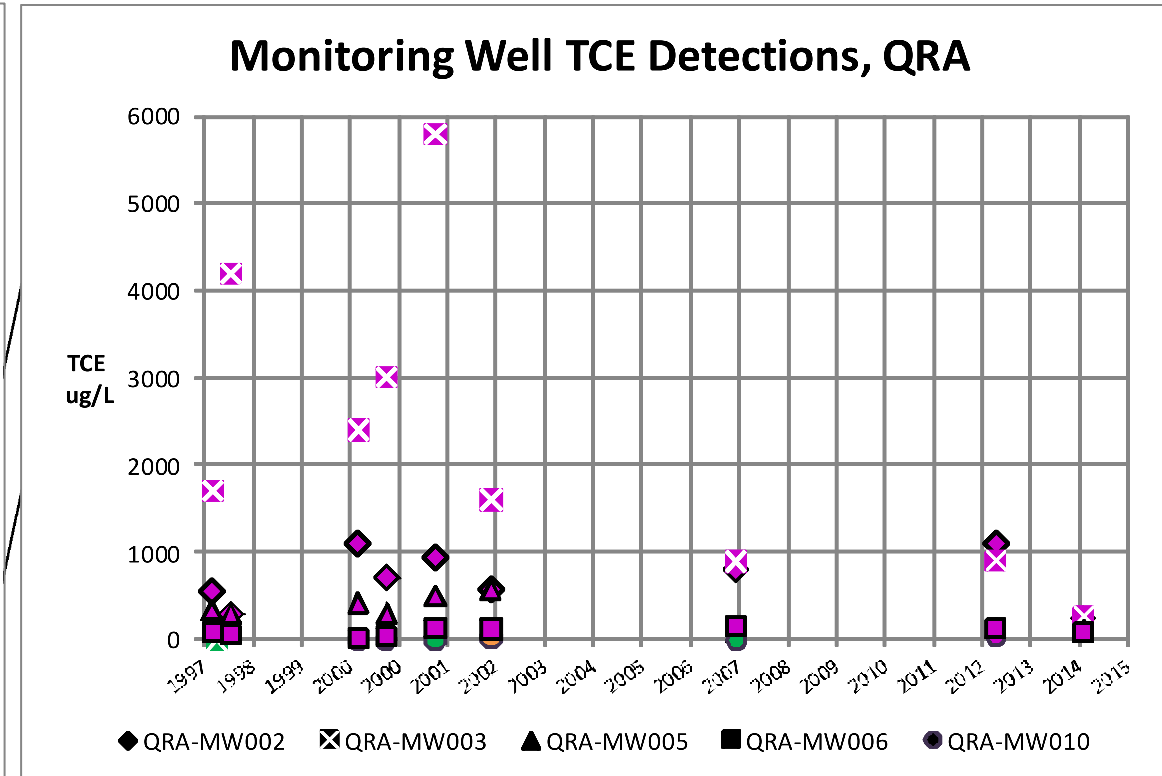
Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Well Plots, Select Private Wells in Study Area

DRN. BY: IJP CHKD. BY: HB 11/10/2015	AECOM	FIG. NO. 4-8

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\4-8 Well Plots private.mxd





Well Type

Monitoring Well, Max TCE > 5 µg/L

Private Well, Max TCE > 5 µg/L

Building

Fence

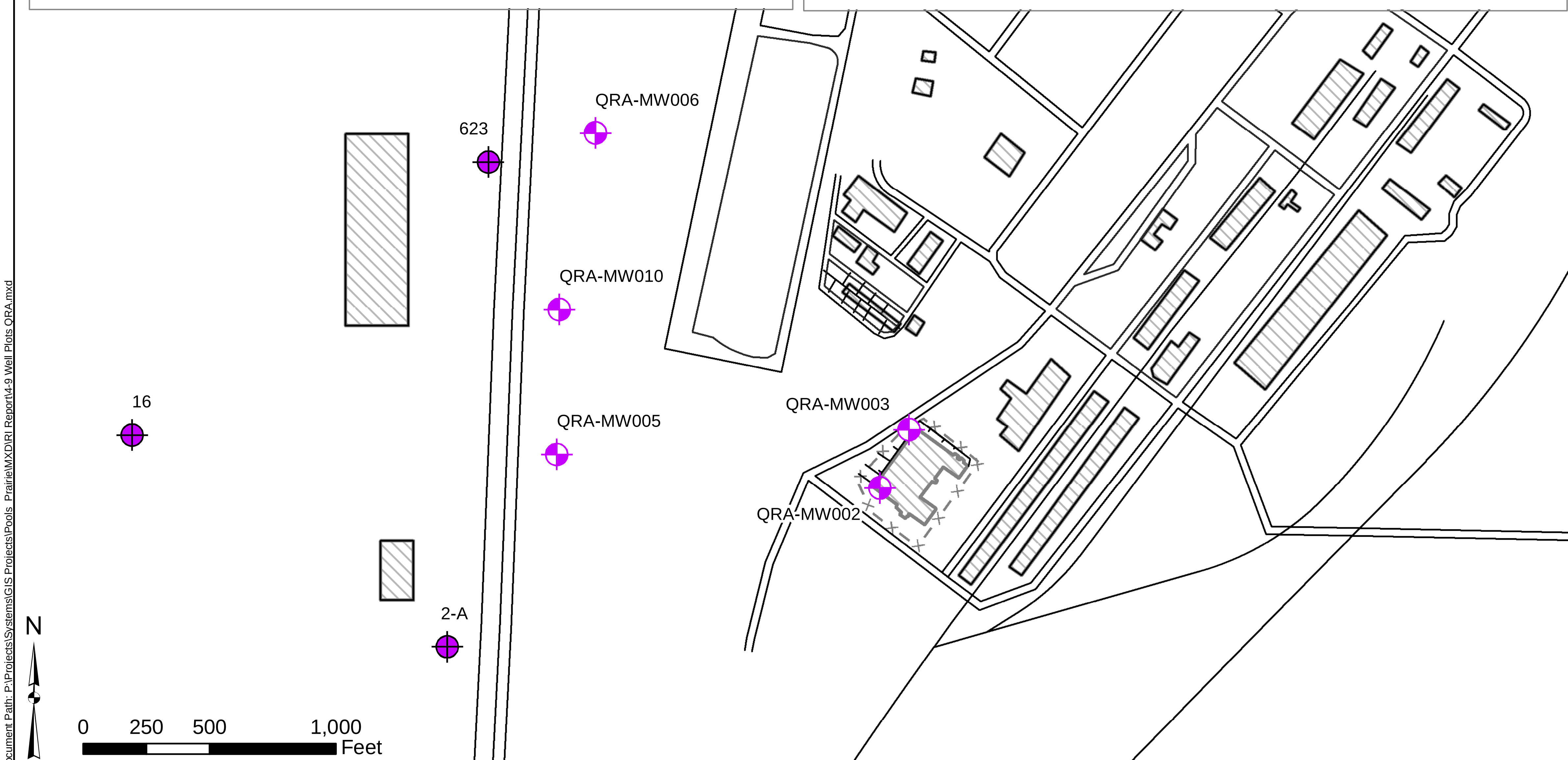
Pavement

Notes:
1. Wells were selected for inclusion in the figure by the following criteria:

a. Detected TCE concentrations above 5 µg/L.

b. Data from both before and after 2005-2007, when soil vapor exctraction (SVE) was implemented at the site.

2. Non Detects are represented on the plots as zeroes.



Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

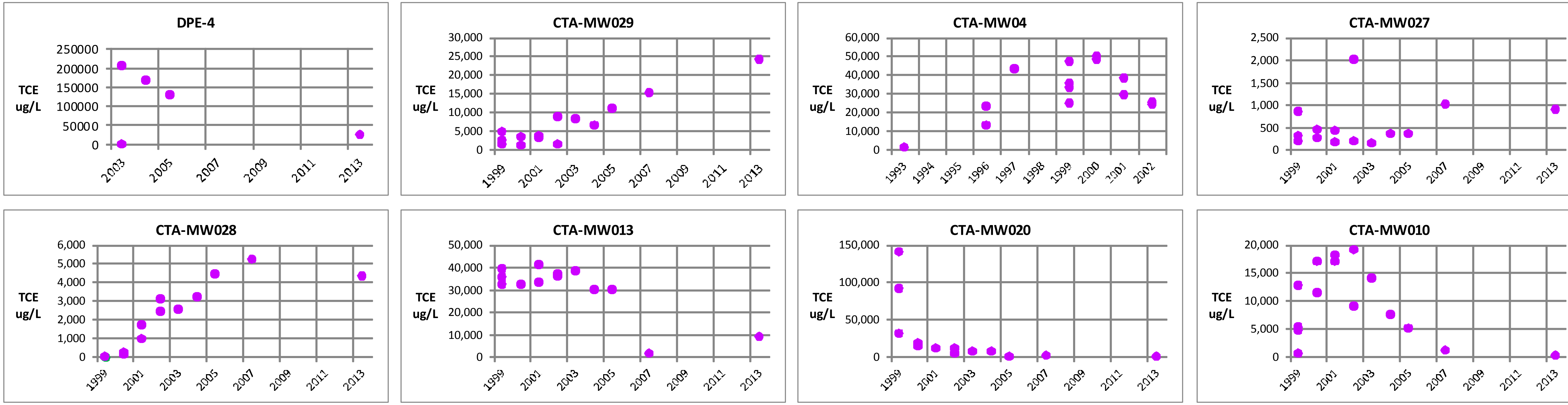
2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

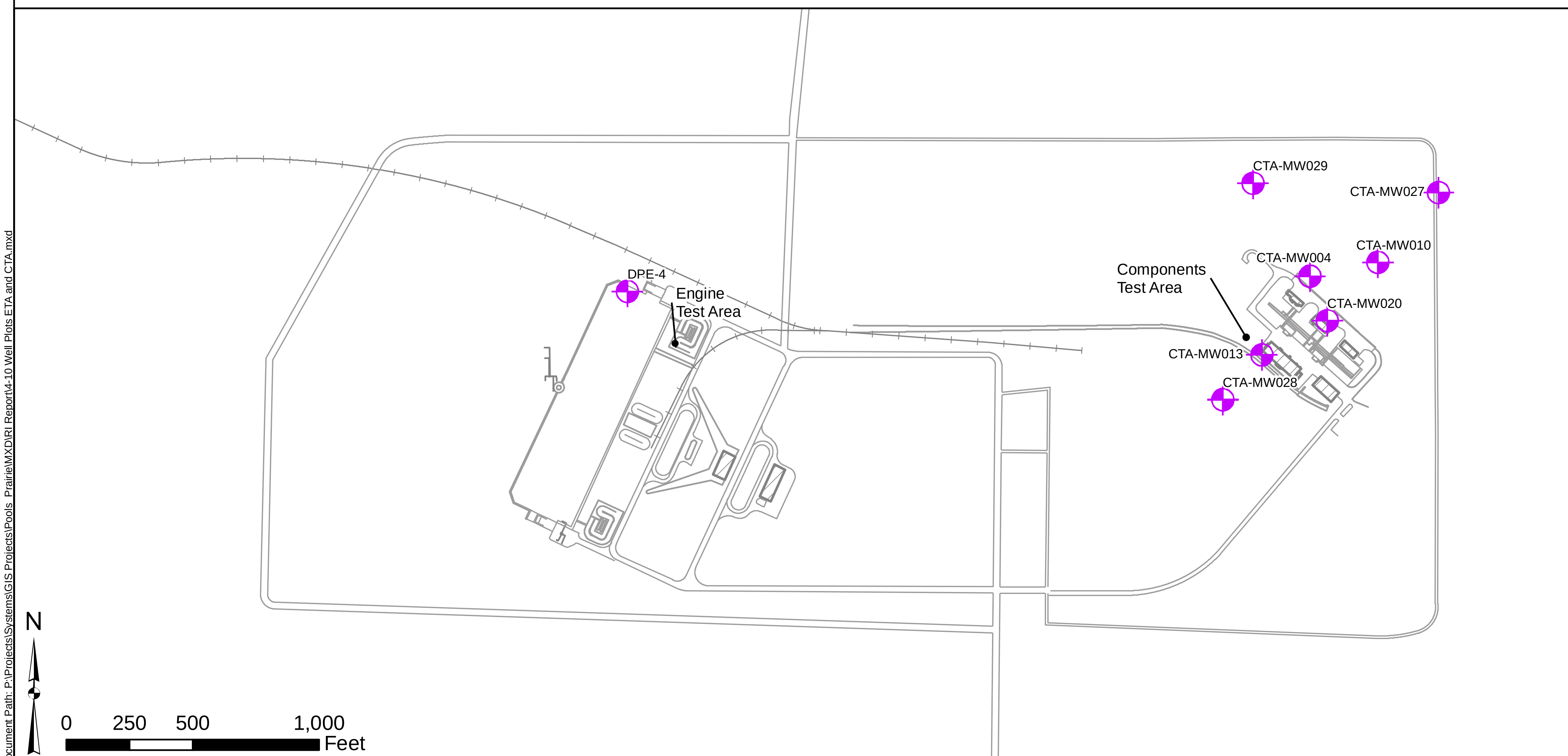
Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Well Plots, Select Wells
in Quince Road Area

DRN. BY: IJP CHKD. BY: HB 11/10/2015	AECOM	FIG. NO. 4-9

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\4-9 Well Plots QRA.mxd





Well Type

Monitoring Well, Max TCE > 5 µg/L

Notes:

1. Wells were selected for inclusion in the figure by the following criteria:

a. Detected TCE concentrations above 5 µg/L.

b. All CTA wells (except MW004) have data before and after 2004 when removal activities were performed at this site. At the ETA, DPE-4 has data from before and after 2007-2008 when removal activies were completed.

2. Non Detects are represented on the plots as zeroes.

Data Source:

1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Well Plots, Select Monitoring Wells in ETA/CTA

DRN. BY: IJP CHKD. BY: HB 11/10/2015	AECOM	FIG. NO. 4-10

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\4-11 Well Plots MPA.mxd

Well Type

Monitoring Well, Max TCE > 5 µg/L

Notes:
1. Wells were selected for inclusion in the figure by the following criteria: MW005, MW011 and MW017 have had the highest TCE detections in monitoring wells at the site.

2. Non Detects are represented on the plots as zeroes.

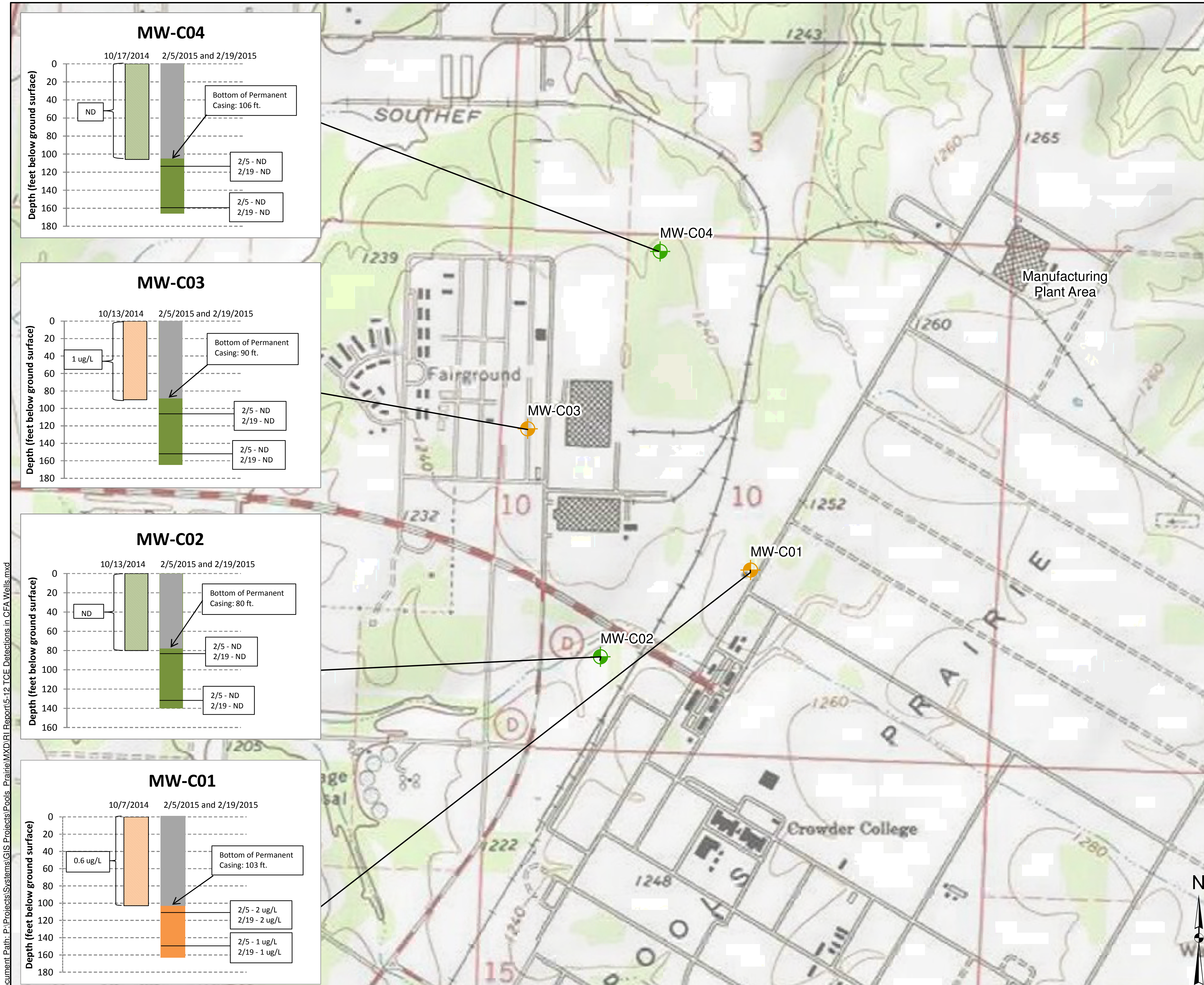
Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Well Plots, Select Monitoring Wells in MPA

DRN. BY: IJP CHKD. BY: HB 11/16/2015	AECOM	FIG. NO. 4-11



Max TCE Detected

No TCE Detected Above Detection Limit

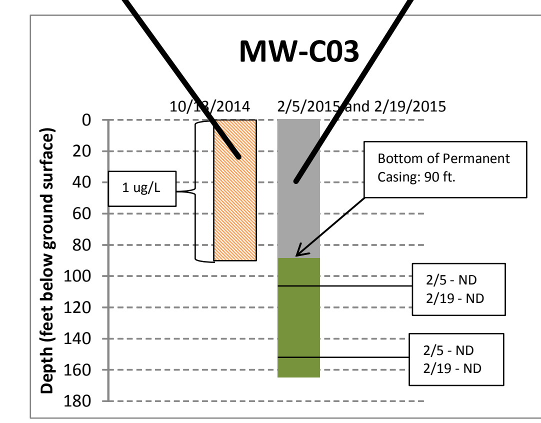
TCE <= 5 µg/L

Notes:

1. Wells were drilled in late 2014. An analytical sample was taken from each well from the uncased zone prior to completion of drilling and installation of permanent casing. Subsequently, after drilling was complete, each well was sampled at various depths using diffusion bags. These sampling depths are reflected in the annotations for each well.

Well Before Casing was Installed

Well After Casing was Installed (Shading indicates maximum TCE detection)



0 500 1,000 2,000 Feet

N

Pools Prairie Superfund Site
Newton County, Missouri

PROJECT NO. 60419811

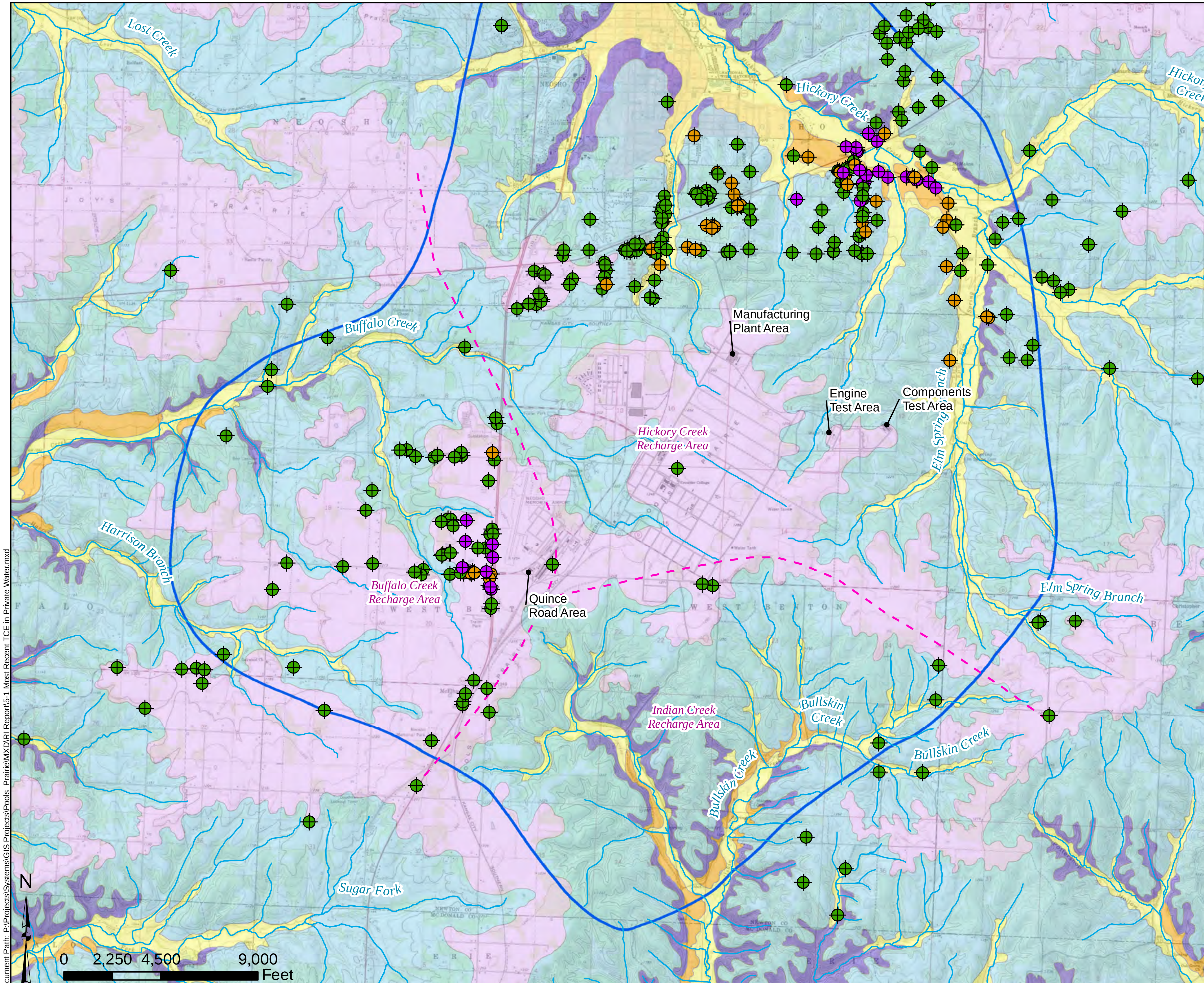
TCE Detections in Phase 1 RI Installed Central Focus Area Wells

DRN. BY: IJP
CHKD. BY: HB
9/14/2015

AECOM

FIG. NO. 4-12

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\5-12 TCE Detections in CFA Wells.mxd



TCE in Private Water

Most Recent TCE Detection

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L
- Inferred Recharge Area
- Phase 1 RI Study Area

Surface Geology

- Colluvium
- Shallow or Exposed Bedrock
- Residuum with Fragipan
- Terrace
- Alluvium and Related

Notes:
1. Private water sources shown include both those investigated during the Phase 1 RI and those investigated historically.

Data Source:
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

3. Surface Geology data from Missouri Department of Natural Resources, Missouri Geological Survey, Digitized from the Surficial Materials Map of Missouri by John W. Whitfield, 1999

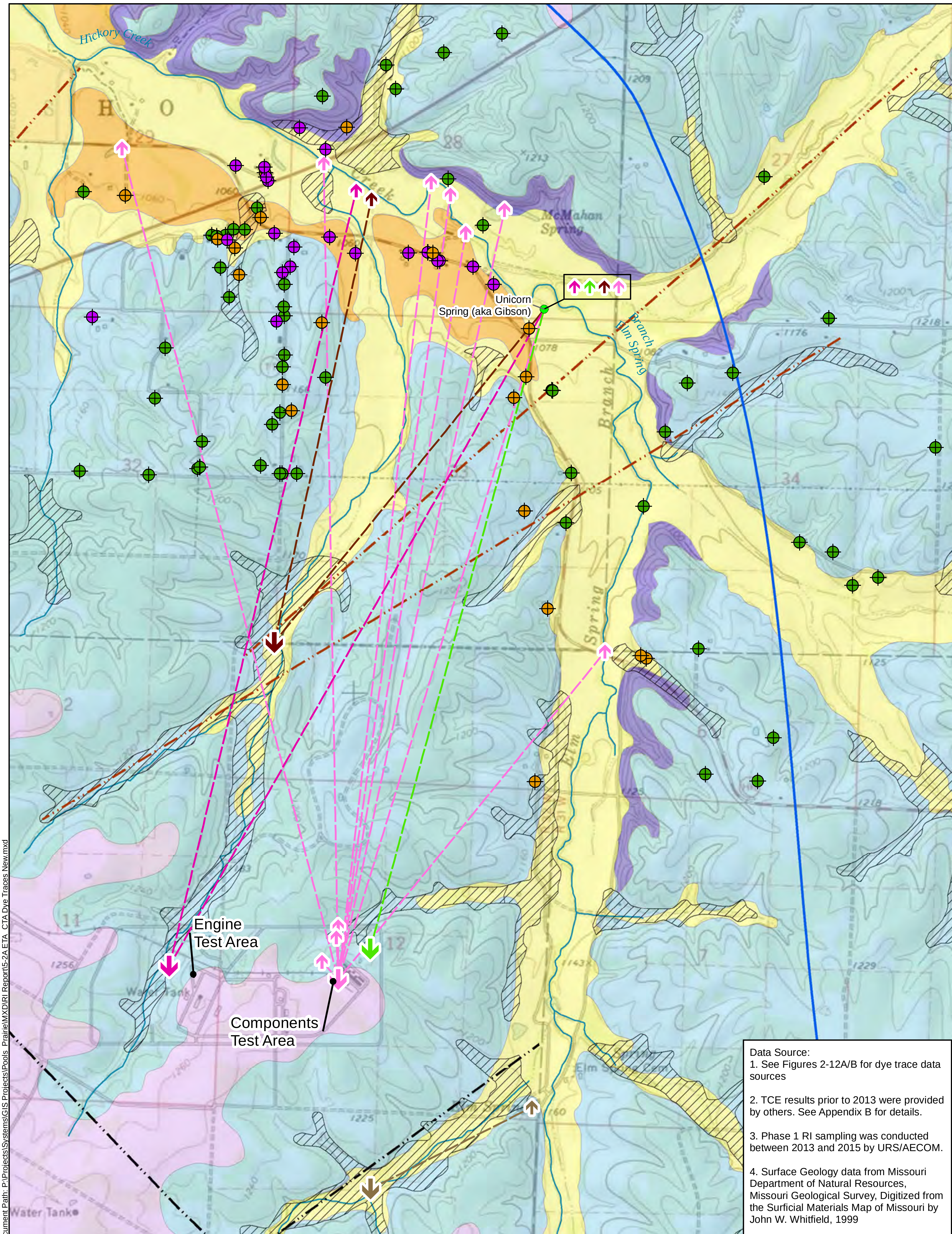
Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Most Recent TCE Detections in Private Water

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 5-1

Document Path: P:\Projects\GIS Projects\Pools_Prairie\MXD\RI Report\5-1 Most Recent TCE in Private Water.mxd

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed



Data Source:
1. See Figures 2-12A/B for dye trace data sources
2. TCE results prior to 2013 were provided by others. See Appendix B for details.
3. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.
4. Surface Geology data from Missouri Department of Natural Resources, Missouri Geological Survey, Digitized from the Surficial Materials Map of Missouri by John W. Whitfield, 1999

CC-5 (Component Testing Area Trace)
- Detect Station
- Introduction Point

CC-4 (Rocket Engine Test Stand Trace)
- Detect Station
- Introduction Point

CC-2 (Hickory Creek Trace)
- Detect Station
- Introduction Point

CC-1 (Elm Spring Trace)
- Detect Station
- Introduction Point

99-03 (MW13 Trace)
- Detect Station
- Introduction Point
- Phase 1 RI Study Area
- Bedrock Lineaments (Whitfield 1999)
- Additional Lineament (AECOM)
- Hydrologic Soil Group A

TCE in Private Water
Most Recent TCE Detection
- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L

Surface Geology
- Colluvium
- Shallow or Exposed Bedrock
- Residuum with Fragipan
- Terrace
- Alluvium and Related

0 1,000 2,000 4,000 Feet

Notes:
1. Private water sources shown include both those investigated during the Phase 1 RI and those investigated historically.

Pools Prairie Superfund Site
Newton County, Missouri

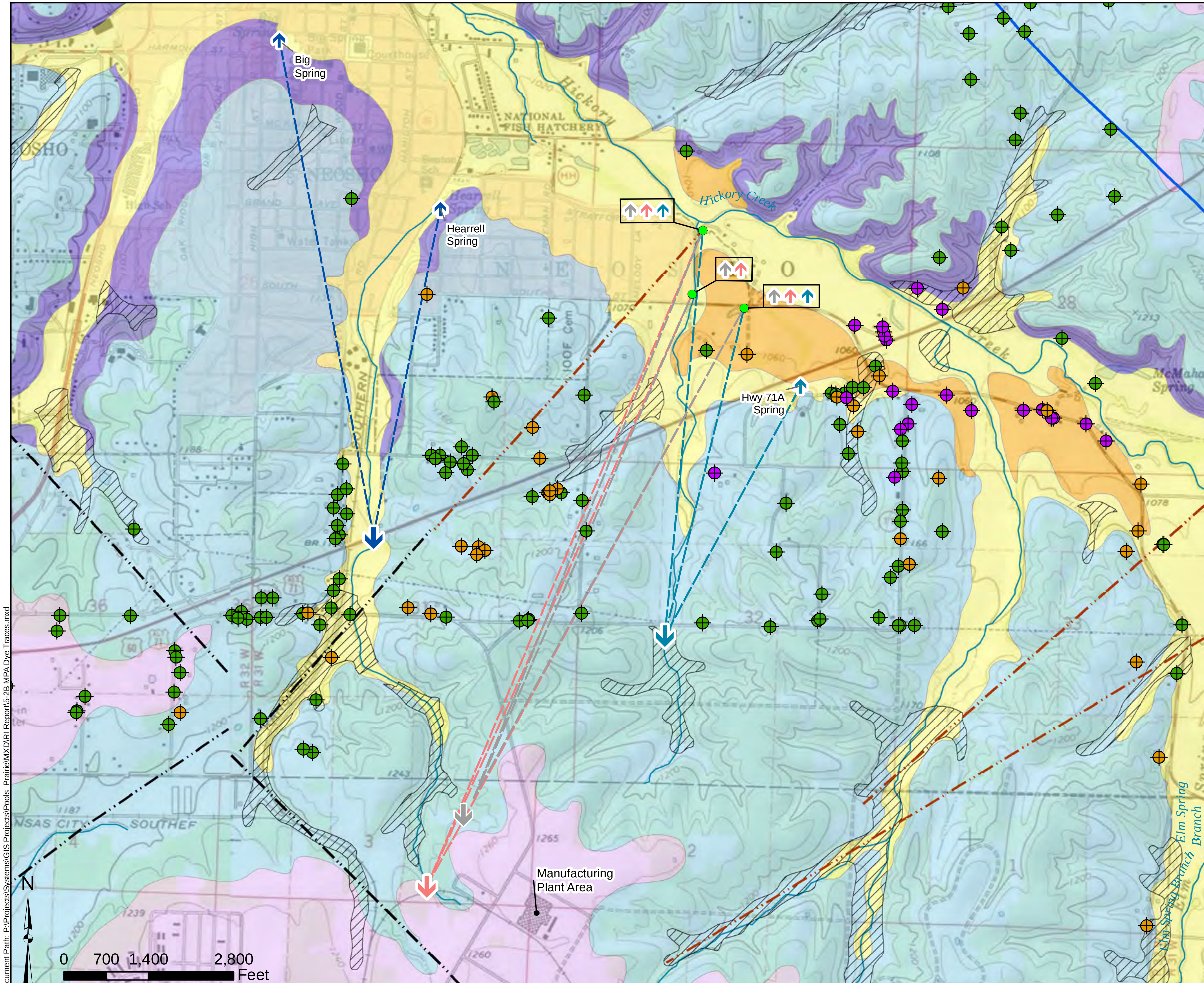
PROJECT NO. 60419811

Consolidated Data Supporting Shallow Groundwater Flow, ETA and CTA

DRN. BY: IJP
CHKD. BY: HB
12/2/2015

AECOM

FIG. NO. 5-2A



97-01 (Old Mine 1 Trace)

Detect Station

Introduction Point

97-02 (Industry Area 1 Trace)

Detect Station

Introduction Point

96-15 (MDC Trace)

Detect Station

Introduction Point

96-16 (Highway 71A Trace)

Detect Station

Introduction Point

TCE in Private Water

Most Recent TCE Detection

No TCE Detected Above Detection Limit

TCE <= 5 µg/L

TCE > 5 µg/L

Phase 1 RI Study Area

Bedrock Lineaments (Whitfield 1999)

Additional Lineament (AECOM)

Hydrologic Soil Group A

Surface Geology

Colluvium

Shallow or Exposed Bedrock

Residuum with Fragipan

Terrace

Alluvium and Related

Notes:

1. Private water sources shown include both those investigated during the Phase 1 RI and those investigated historically.

Data Source:

1. See Figure 3-7B for dye trace sources.

2. TCE results prior to 2013 were provided by others. See Appendix B for details.

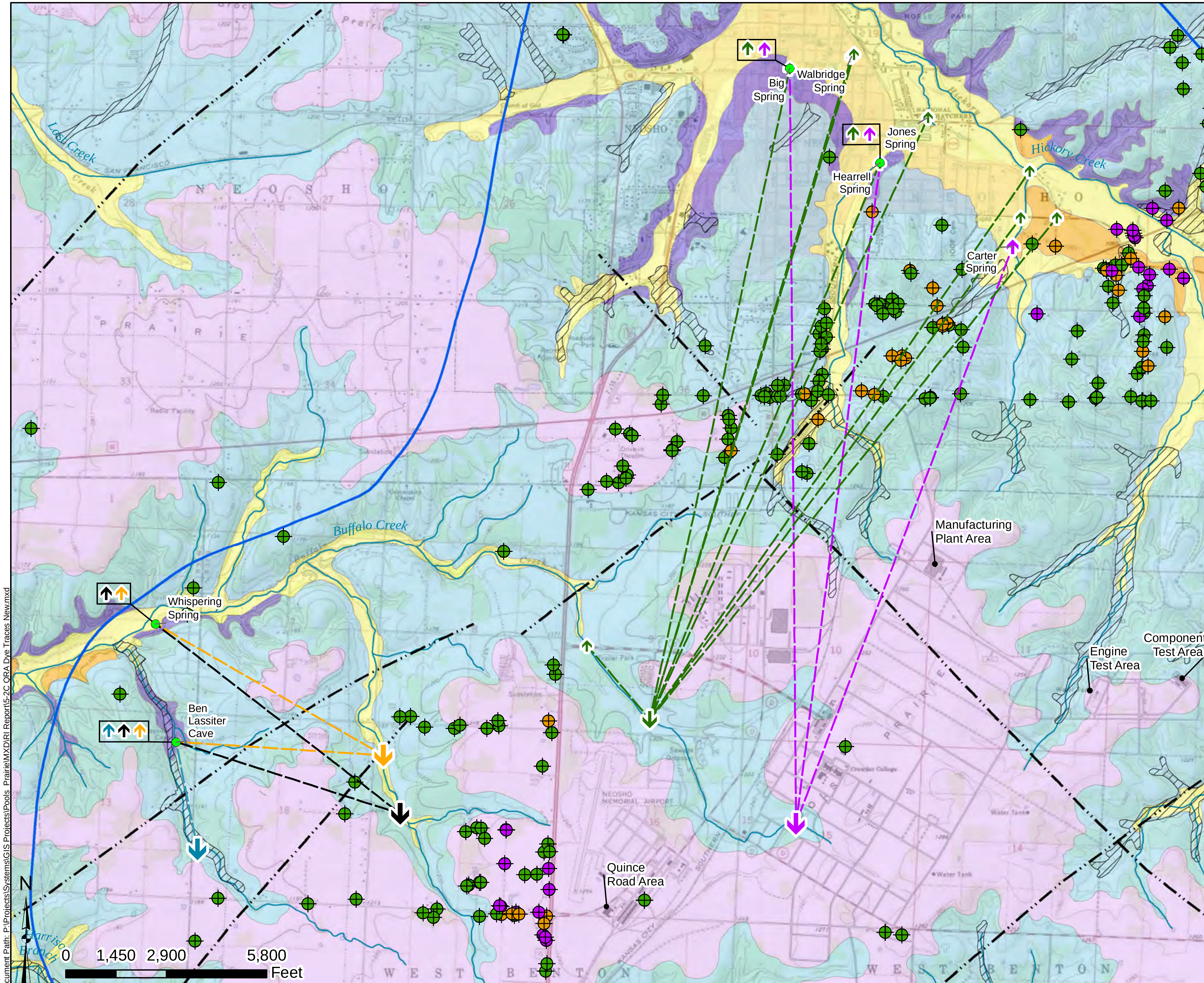
3. Phase 1 RI Sampling was conducted from 2013-2015 by URS/AECOM field staff.

4. Surface Geology data from Missouri Department of Natural Resources (MDNR), Missouri Geological Survey, Digitized from the Surficial Materials Map of Missouri by John W. Whitfield, 1999

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Consolidated Data Supporting Groundwater Flow, MPA

DRN. BY: IJP CHKD. BY: HB 12/2/2015	AECOM	FIG. NO. 5-2B



DT-1 (Buffalo Creek Tributary Trace)

Detect Station

Introduction Point

DT-2 (Buffalo Creek Tributary Trace 2)

Detect Station

Introduction Point

11-02 (Buffalo Creek Trace)

Detect Station

Introduction Station

Ben Lassiter Cave Branch Trace

Detect Station

Introduction Point

CC-7 (Main Gate Trace)

Detect Station

Introduction Point

TCE in Private Water

Most Recent TCE Detection

No TCE Detected Above Detection Limit

TCE <= 5 µg/L

TCE > 5 µg/L

Phase 1 RI Study Area

Bedrock Lineaments

Hydrologic Soil Group A

Surface Geology

Colluvium

Shallow or Exposed Bedrock

Residuum with Fragipan

Terrace

Alluvium and Related

Notes:

1. Private water sources shown include both those investigated during the Phase 1 RI and those investigated historically.

Data Source:

1. See Figure 3-7A for dye trace data sources

2. TCE results prior to 2013 were provided by others. See Appendix B for details.

3. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

4. Surface Geology data from Missouri Department of Natural Resources (MDNR), Missouri Geological Survey, Digitized from the Surficial Materials Map of Missouri by John W. Whitfield, 1999

Pools Prairie Superfund Site
Newton County, Missouri

PROJECT NO.
60419811

Consolidated Data Supporting
Shallow Groundwater Flow, QRA

DRN. BY: IJP
CHKD. BY: HB
12/1/2015

AECOM

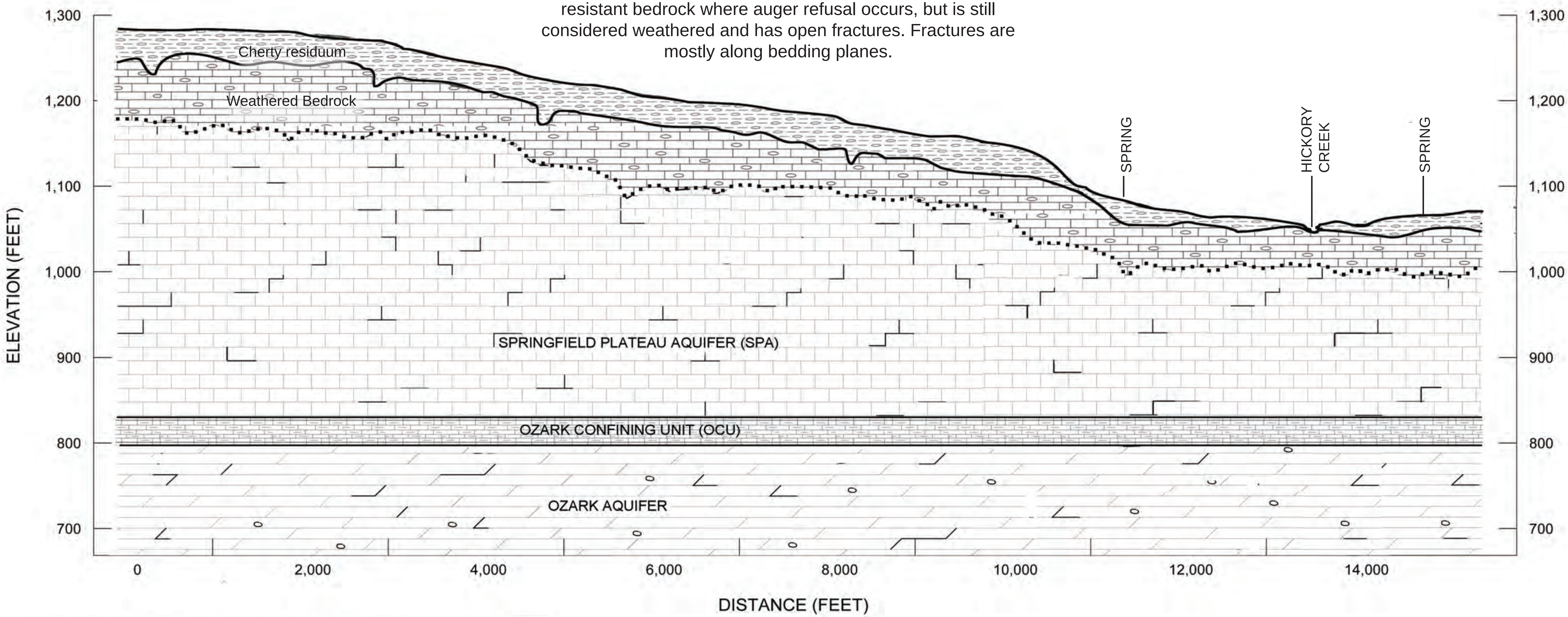
FIG. NO.
5-2C

Document Path: P:\Projects\Systems\GIS Projects\Pools Prairie\MXD\RI Report\5-2C QRA Dye Traces New.mxd

In the upland areas, the Warsaw formation is the uppermost bedrock unit.

The **weathered bedrock** is the zone with the most open fractures observed in televiewers, and where grout loss and circulation loss occurred during monitoring well installation. This is the zone above competent bedrock, where MDNR requires permanent casing in wells. It ranges from highly weathered bedrock that can be easily augured to more resistant bedrock where auger refusal occurs, but is still considered weathered and has open fractures. Fractures are mostly along bedding planes.

In stream valleys, the Burlington Keokuk is the uppermost bedrock unit. Springs are typically located in this formation, close to the Warsaw contact. According to Whitfield 1996, the Burlington Keokuk is jointed. Lineaments shown on the bedrock maps may be joints in the Burlington Keokuk.



Detail of surface and near-surface strata, from Whitfield 1996.
The **cherty residuum** can range from very low permeability material (fragipan, approximately 30 inches thick, overlies upland areas) to very high permeability material (thick chert zones, in upland stream valleys or on slopes where fragipan has been stripped off).

LEGEND:

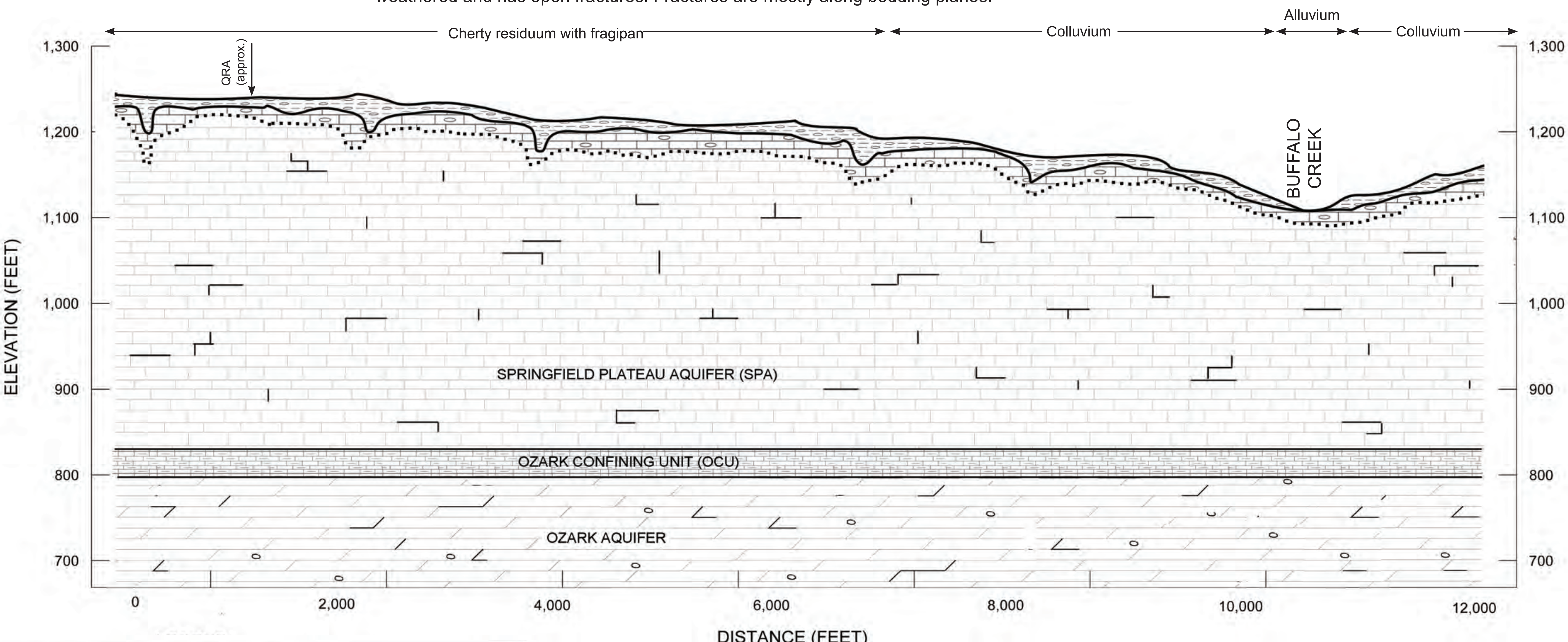
- CHERTY RESIDUUM
- WEATHERED BEDROCK
- SPRINGFIELD PLATEAU AQUIFER (MOSTLY CHERTY LIMESTONE)
- OZARK CONFINING UNIT (SHALE, LIMESTONE, SHALE)
- OZARK AQUIFER (LIMESTONE, SOME DOLOMITE)
- THICKER LINES INDICATE SECONDARY POROSITY
- VUGS

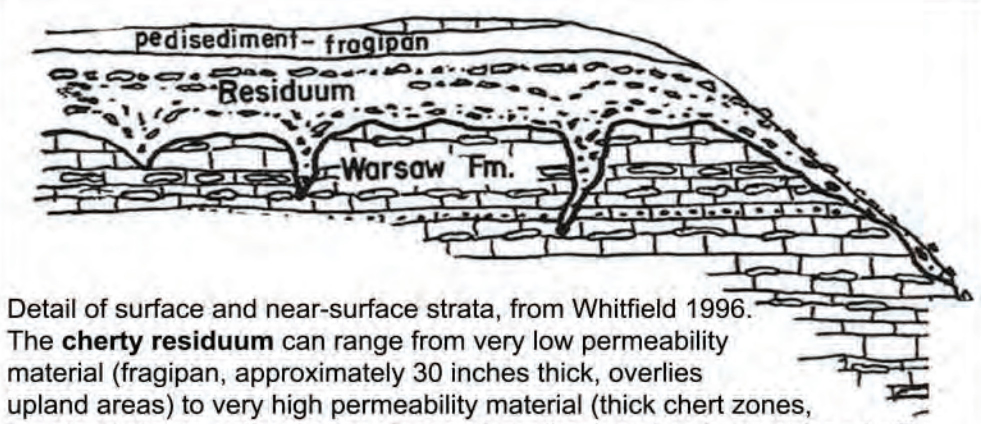
Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Conceptual Site Model Profile - ETA, CTA, and MPA	
DRN. BY: HRB CHKD. BY: MCH 11/2/15 AECOM	FIG. NO. 5-3

In the upland areas, the Warsaw formation is the uppermost bedrock unit.

The **weathered bedrock** is the zone with the most open fractures observed in televiewers, and where grout loss and circulation loss occurred during monitoring well installation. This is the zone above competent bedrock, where MDNR requires permanent casing in wells. It ranges from highly weathered bedrock that can be easily augered to more resistant bedrock where auger refusal occurs, but is still considered weathered and has open fractures. Fractures are mostly along bedding planes.

In stream valleys, the Burlington Keokuk is the uppermost bedrock unit. Springs are typically located in this formation, close to the Warsaw contact. According to Whitfield 1996, the Burlington Keokuk is jointed. Lineaments shown on the bedrock maps may be joints in the Burlington Keokuk.



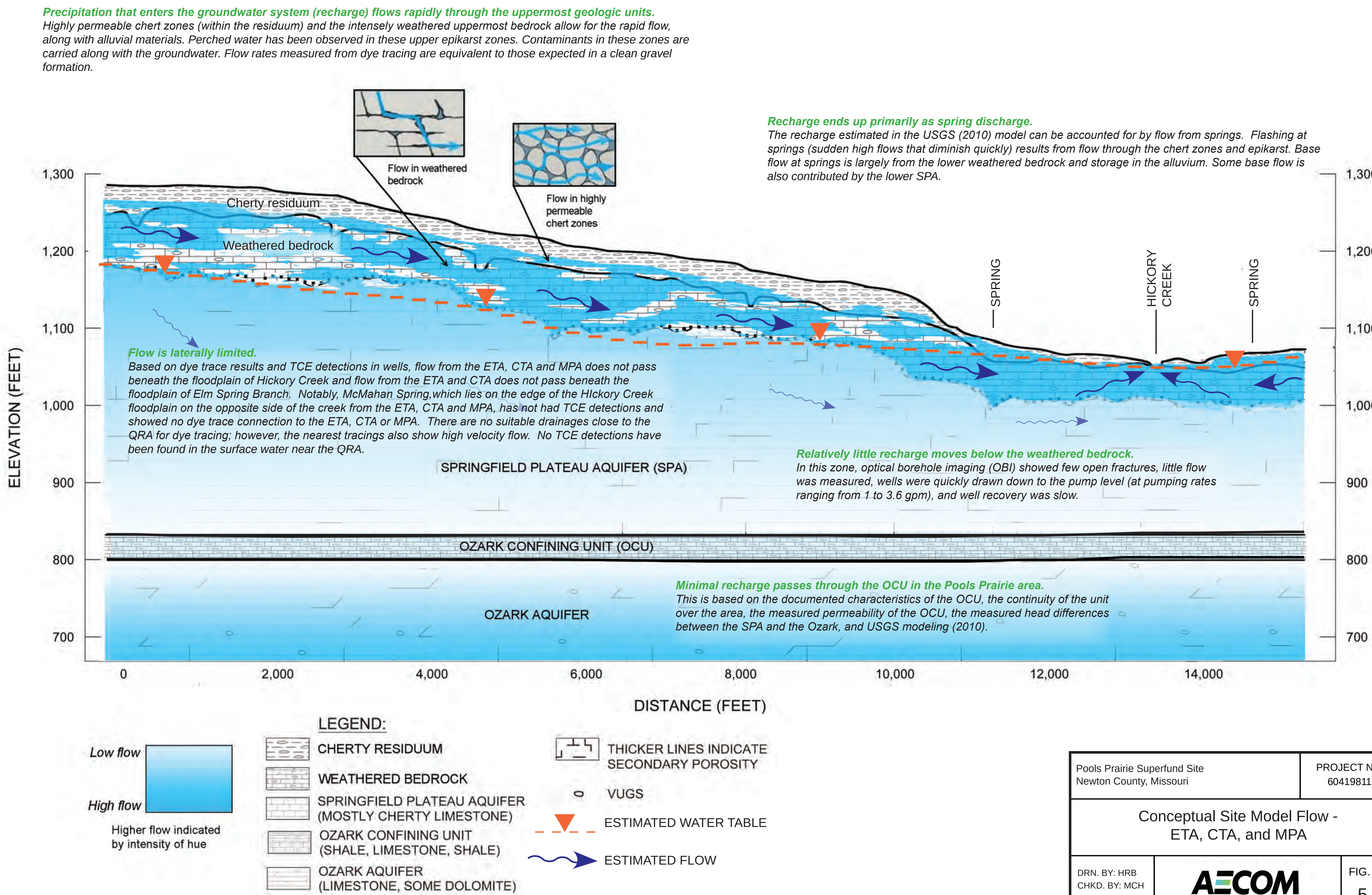


Detail of surface and near-surface strata, from Whitfield 1996. The **cherty residuum** can range from very low permeability material (fragipan, approximately 30 inches thick, overlies upland areas) to very high permeability material (thick chert zones, in upland stream valleys or on slopes where fragipan has been stripped off).

LEGEND:

- CHERTY RESIDUUM
- WEATHERED BEDROCK
- SPRINGFIELD PLATEAU AQUIFER (MOSTLY CHERTY LIMESTONE)
- OZARK CONFINING UNIT (SHALE, LIMESTONE, SHALE)
- OZARK AQUIFER (LIMESTONE, SOME DOLOMITE)
- THICKER LINES INDICATE SECONDARY POROSITY
- VUGS

Pools Prairie Superfund Site Newton County, Missouri		PROJECT NO. 60419811
Conceptual Site Model Profile - QRA		
DRN. BY: HRB CHKD. BY: MCH 11/2/15	AECOM	FIG. NO. 5-4



Pools Prairie Superfund Site
Newton County, Missouri

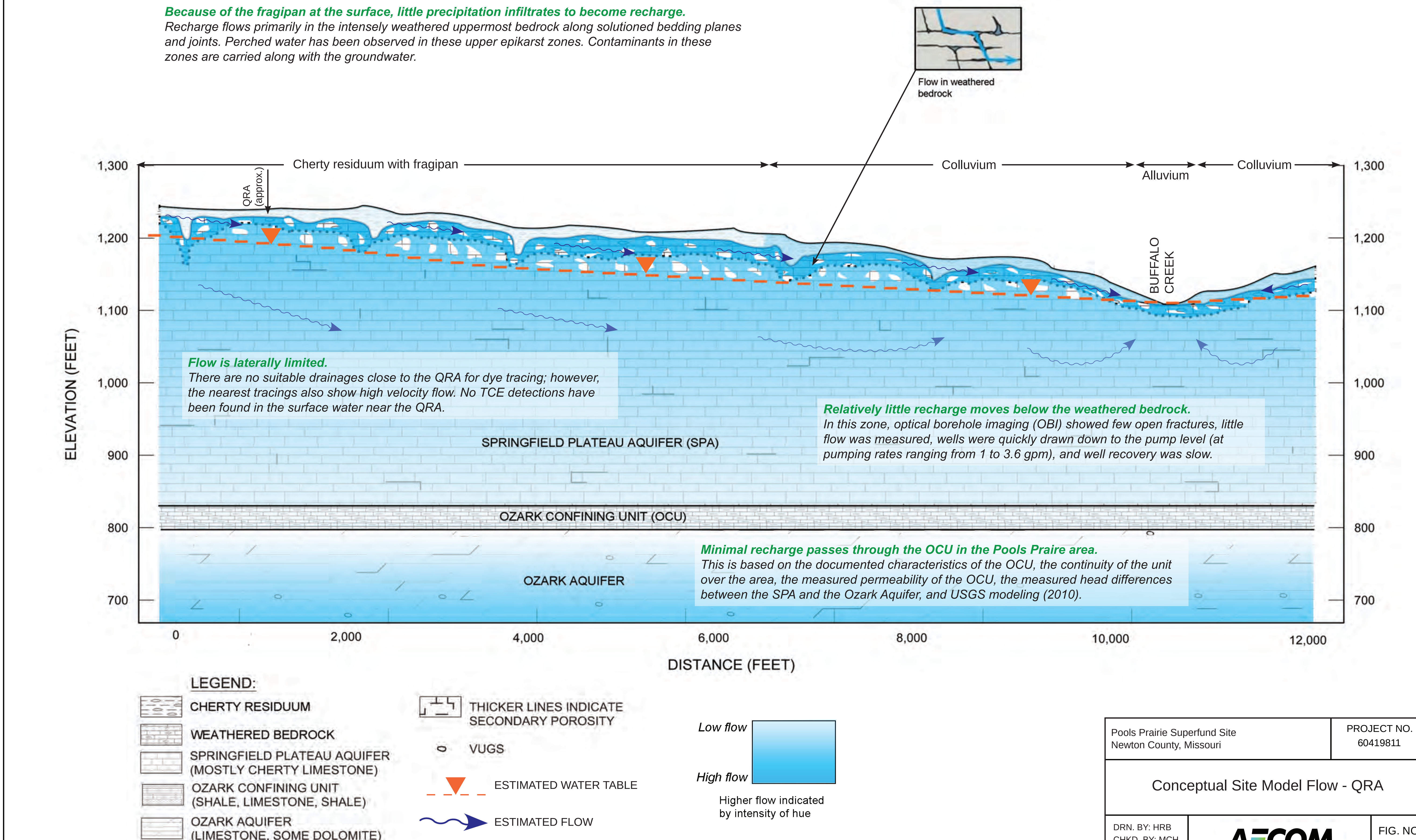
PROJECT NO. 60419811

Conceptual Site Model Flow - ETA, CTA, and MPA

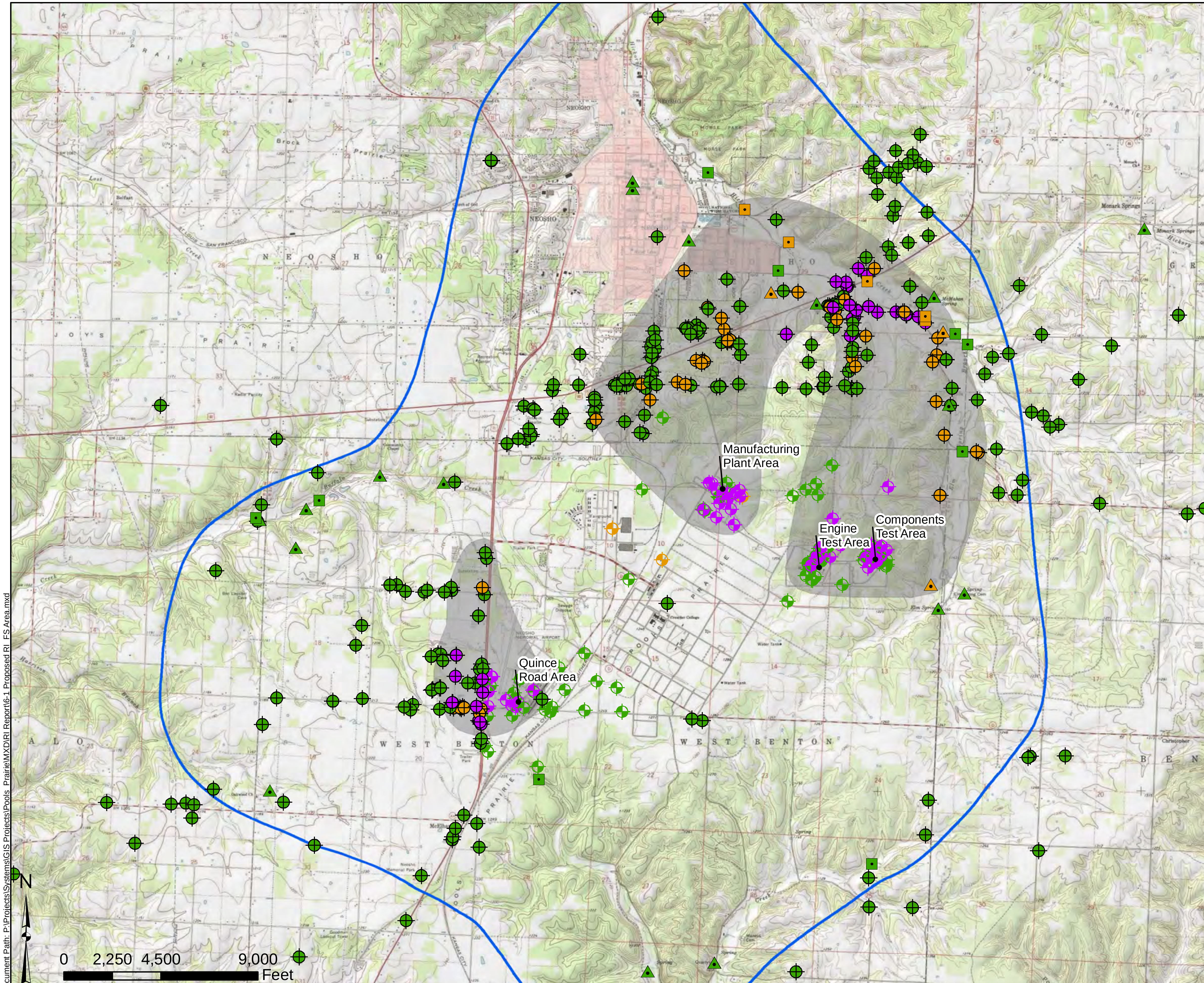
DRN. BY: HRB
CHKD. BY: MCH
04/27/16

AECOM

FIG. NO. 5-5



Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Conceptual Site Model Flow - QRA	
DRN. BY: HRB CHKD. BY: MCH 04/27/16	FIG. NO. 5-6



Document Path: P:\Projects\Systems\GIS Projects\Pools Prairie\MXD\RI Report\6-1 Proposed RI FS Area.mxd

TCE Detections in Sampled Streams (Phase 1 RI)

- No TCE Detected Above Detection Limit
- TCE Detected

TCE Detections in Sampled Springs (Phase 1 RI)

- No TCE Detected Above Detection Limit
- TCE Detected

Most Recent TCE in Private Water (Historic and Phase 1 RI)

- No TCE Detected Above Detection Limit
- TCE <= 5 µg/L
- TCE > 5 µg/L

Max TCE in Monitoring Wells (Phase 1 RI)

- No TCE Detected Above Detection Limit
- TCE <= 5 ug/L
- TCE > 5 ug/L
- Proposed Boundary of RI/FS
- Phase 1 RI Study Area

Notes:

1. See report for details on how the proposed focus area boundary was developed.

2. Private water sources shown include both those investigated during the Phase 1 RI and those investigated historically.

Data Source:

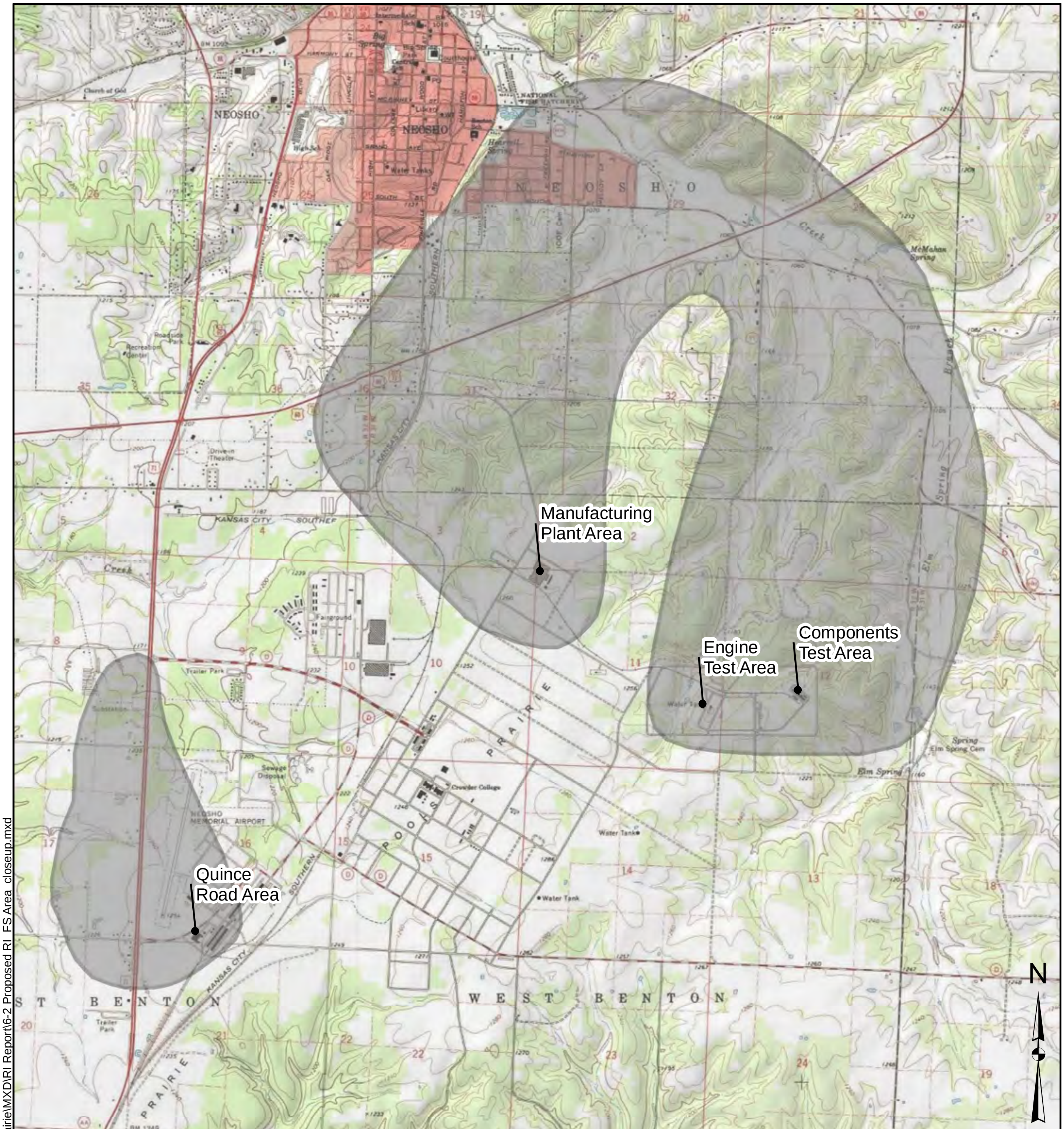
1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/AECOM.

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811

Proposed Area to be Included in
Remedial Investigation/Feasibility Study

DRN. BY: IJP CHKD. BY: HB 12/1/2015	AECOM	FIG. NO. 6-1



Proposed Boundary of RI/FS

Data Source:

1. TCE results prior to 2013 were provided by others. See Appendix B for details.

2. Phase 1 RI sampling was conducted between 2013 and 2015 by URS/ AECOM

Pools Prairie Superfund Site Newton County, Missouri	PROJECT NO. 60419811
Proposed Area to be Included in Remedial Investigation/Feasibility Study	
DRN. BY: IJP CHKD. BY: HB 12/1/2015 AECOM	FIG. NO. 6-2

Document Path: P:\Projects\Systems\GIS Projects\Pools_Prairie\MXD\RI Report\6-2 Proposed RI_FS Area_closeup.mxd